LUDLUM STEEL

LUDLUM

LUDLUM STEEL COMPANY
WATERVLIET, N. Y.
U. S. A.

BRANCH OFFICES

Boston
Chicago
Cleveland
Detroit
Los Angeles
New York
Philadelphia
San Francisco

WAREHOUSES

Carrying complete stocks

Chicago
Detroit
Los Angeles
Millersburg, Pa.
San Francisco
Watervliet

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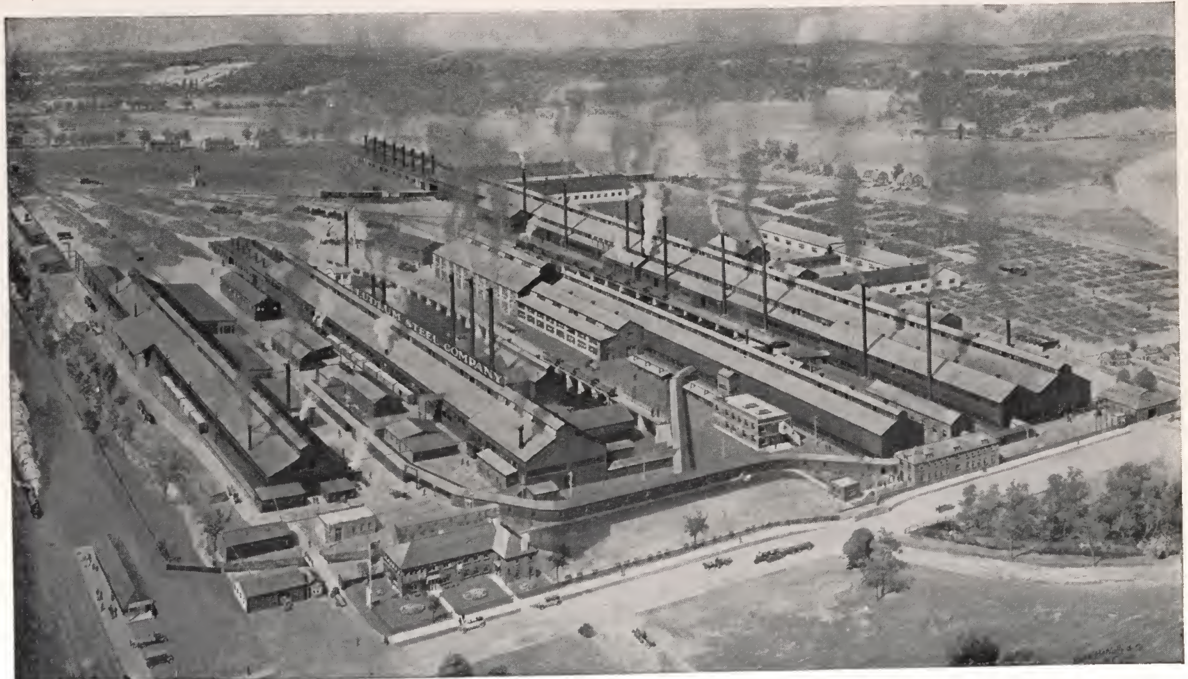


Airplane view of the Ludlum Steel Company's plant at Watervliet, New York, a completely equipped, modern, tool steel mill.

INTRODUCTION

Original plant at Pompton New Jersey. We started here in 1854 continually enlarging our facilities and later moving to Watervliet, New York. Ludlum is one of the pioneers in American tool steel history.

INTRODUCTION

The Ludlum Steel Company is one of the oldest established high grade tool steel mills in America, founded in the year 1854. Our Pompton brand tool steel is probably one of the most widely known high grade American steels. Our mill has grown from a comparatively small crucible plant to one of the largest high grade tool steel producing mills in the country. We make nothing but high grade tool steel; therefore our melters and rolling mill men are highly skilled in the expert handling of this special steel.

The crucible process is one of the oldest methods of making high grade steel. The product is governed by the raw material used; therefore even though the highest form of skilled control be applied to the melting and working of this steel, it is of no avail if the raw material contains some unlooked-for impurities. That is one of the reasons why various melts of crucible steel, made from the same high grade raw material, differ very largely in their work and efficiency. The Ludlum Steel Company, recognizing this very serious defect in the highest grade crucible steel, started to investigate methods of melting wherein full refining could be accomplished, the crucible process being purely one of remelting.

The basic and acid open hearth process produces a steel which is partly refined, but does not go far enough. It is possible, when the same high grade charge is used as in the crucible process, to produce high grade steel in the open hearth furnace, but this process has many variables and, for that reason, instead of continuously getting a reliable, high grade product, many mysterious things happen to open hearth melts, which are undoubtedly due to occluded gases.

The chemical analysis of high grade crucible steel can be duplicated in the open hearth, but the quality of steel is distinctly different. Twenty years ago, electric furnaces were

being substituted as a very probable means of eradicating the dangerous gases which are to be found in solution in steel. We were pioneers in this investigation, and we have experimented with practically every known type of electric furnace and have developed a special form of "electric crucible furnace" wherein we get all of the benefits common to the crucible and the full refining possible with the electric furnace.

Our customers have found that our steels are purer and give better results in service, than any other type of steel, whether it be crucible or electric. The usual electric furnace, of which there are perhaps a few hundred in operation in this country, has been developed for quantity production. As these furnaces produce a far purer grade of steel than the best open hearth, the opportunities for these furnaces are very great where automobile and structural alloy steels are concerned. These furnaces are therefore manufactured with two ideas in view, quantity and quality.

Our electric crucible furnace, which is the outcome of our many years of experience, produces the highest grade of carbon and alloy tool steels, and has been designed for quality, which is the all important point where high grade tool steel is concerned. Individuality in the production of steel was important in the days of the crucible steel, and is just as important now when superior methods of melting have been developed. It is our opinion, and has been fully substantiated in practice, that the furnaces used for melting tool steel should be designed for that purpose, and that purpose alone.

Pure tool steel in the ingot form can be ruined in the rolling mill if great care is not taken with the reheating and rolling mill temperatures and also in the quality of the mechanical work. We believe that we are the only steel mill in this country which has equipped its reheating furnaces with pyrometer control. These pyrometers give us ready means

of checking up the expert furnacemen's knowledge of temperature, and we have carefully worked out in our laboratory the correct temperatures for reheating steel, the speed at which this steel is to be heated, and the length of time it has to be soaked at various temperatures. We have also investigated the number of passes and the amount of mechanical work in each pass, the temperature at which every grade of steel shall pass through the last roll in the rolling mill, and a definite speed of cooling for the bars. The finishing temperatures and cooling temperatures are carefully checked and controlled by a special form of optical pyrometer. Our hammer shop is controlled in exactly the same way; therefore, we are in a position to claim justifiably that our carbon and alloy tool steels are melted under the best conditions possible and are mechanically worked and heat-treated under the finest methods of practical and scientific control.

Graphic representation cf the location of our plant, showing our unequalled transportation facilities.

CUSTOMERS' INFORMATION

TERMS

The terms are net cash—thirty days, unless otherwise specially agreed.

QUOTATIONS

All quotations are for immediate acceptance, and prices are subject to change without notice.

SALES

Orders and contracts of sale are accepted subject to provision that strikes, fires, accidents, and other causes of delay beyond our control, shall relieve us from prompt fulfillment thereof.

SHIPMENTS

All deliveries are made F. O. B. cars at our works unless otherwise specially arranged. Shipments by express will be made only at customer's request and expense, or whenever the weight is less than the railroad will accept as freight.

EXTRAS

Extra charges will be made in accordance with the classification in this catalogue. Boxing, casing and barrelling will be charged for at cost.

PAYMENTS

Checks and drafts should be drawn to the order of the Ludlum Steel Company, and forwarded to Watervliet, New York.

WARRANTY

We will replace any steel which, if properly selected and used, shall prove defective, but we will not allow claims for labor or damage.

TOOL STEEL AND ALLOY STEEL

HOW TO ORDER

When ordering tool steel always specify the following:

1. The Grade.

2. The size and shape.

3. The carbon-temper or the purpose for which the steel is to be used.

4. Annealed or not.

It is particularly important when ordering tool steel which is to be made into costly tools and dies that the above points should be carefully observed.

In the event of your specifying the grade and purpose for which the steel will be used and omitting to specify the carbon-temper, we will furnish the same temper as the one last supplied you for the same purpose. In the event of no prior purchase having been made for this class of material, we will use our judgment and select the steel which we think is best suited for the purpose.

If bars are to be machined, order at least ¼″ larger than the finished size.

When ordering die blocks, whether forged or cut from the bar, give the following information: the length, the width, and the depth or thickness, allowing at least ⅜″ all over each way for machining.

Tool steel bars run from 6′ to 12′ according to weight. We reserve the right to make up a full bar of two pieces unless otherwise specially ordered. Bars of unusual length can be supplied to order at small extra charge.

TOOL STEEL CLASSIFICATION

APPLYING TO ALL GRADES OF TOOL STEEL EXCEPT HIGH SPEED AND SOME SPECIAL GRADES OF ALLOY TOOL STEEL

Intermediate sizes take the next higher extra
All dimensions inclusive

Round, Square, Octagon and Hexagon

5/8 to 2 inches..Base

Inches	Extra per lb. Cents
2 1/8 to 3	1.0
3 1/8 to 4	1.5
4 1/8 to 5	2.0
5 1/8 to 6	2.5
6 1/8 to 7	3.0
7 1/8 to 8	3.5
8 1/8 to 9	4.0
9 1/8 to 10	5.0
9/16 to 1/2	0.5
7/16 to 3/8	1.0
5/16 and 11/32	2.0
1/4 and 9/32	3.0
3/16	5.0
5/32	10.0
1/8	18.0

Flat

5/8 to 2 inches thick x 9/16 to 2 inches wide........................Base

Inches	Extra per lb. Cents
1/8 x 3/16	20.0
1/8 x 1/4	15.0
1/8 x 5/16	8.0
1/8 x 3/8	4.0
1/8 x 7/16 to 1/2	3.0
1/8 x 9/16 to 7	2.0
1/8 x 7 1/8 to 8	3.0
3/16 x 1/4	5.0
3/16 x 5/16	4.0
3/16 x 3/8	3.0
3/16 x 7/16 to 5/8	2.0
3/16 x 11/16 to 2	1.5
3/16 x 2 1/8 to 7	1.0
3/16 x 7 1/8 to 8	2.0
1/4 x 5/16 to 3/8	2.0
1/4 x 7/16 to 5/8	1.5
1/4 x 11/16 to 2	1.5
1/4 x 2 1/8 to 7	1.0
1/4 x 7 1/8 to 8	2.0
5/16 x 3/8 to 5/8	1.5
5/16 x 11/16 to 8	1.0
3/8 x 7/16 to 8	1.0
7/16 x 1/2 to 8	1.0
1/2 x 9/16 to 8	1.0
9/16 x 2 1/8 to 8	1.0
5/8 to 2 x 2 1/8 to 7	1.0
5/8 to 1 3/4 x 7 1/8 to 8	1.0
1 7/8 to 2 x 7 1/8 to 8	1.5
2 1/8 to 3 x 2 1/8 to 5	1.0
2 1/8 to 3 x 5 1/8 to 8	1.5
3 1/8 to 4 x 3 1/8 to 6	1.5
3 1/8 to 4 x 6 1/8 to 8	2.0
4 1/8 to 5 x 4 1/8 to 7	2.0
4 1/8 to 5 x 7 1/8 to 8	2.5
5 1/8 to 6 x 5 1/8 to 8	2.5
6 1/8 to 7 x 6 1/8 to 7	3.0
6 1/8 to 8 x 7 1/8 to 8	3.5

TOOL STEEL CLASSIFICATION

(*Continued*)

Annealing

	Cents per lb.
Annealing Carbon and Alloy Tool Steels	1

Cutting to Specified Single and Multiple Lengths

	Cents per lb.
24 inches and over	0.5
18 to 23 15/16 inches	1.0
12 to 17 15/16 inches	1.5
6 to 11 15/16 inches	2.0

Less than 6 inches, special prices.

Minimum cutting charge, 25 cents.

Forged Disc Classification

Weight	Extra per lb. Cents
Above 25 lbs.	3
15 to 25 lbs.	5
10 to 15 lbs.	6
7½ to 10 lbs.	7
5 to 7½ lbs.	8
3 to 5 lbs.	9
2 to 3 lbs.	11
1 to 2 lbs.	12

Under 1 lb., special price.

Above extras are for discs ½ inch thick and over; thinner discs at special prices.

Annealing 1 cent per lb.

Forged Die Block Classification

Weight	Extra per lb. Cents
Above 25 lbs.	2
15 to 25 lbs.	3
10 to 15 lbs.	5
7½ to 10 lbs.	7
5 to 7½ lbs.	8
3 to 5 lbs.	9
2 to 3 lbs.	11
1 to 2 lbs.	12

Under 1 lb., special price.

Annealing, 1 cent per lb.

Forged Ring Classification

Prices upon application.

TUNGSTEN-STEEL CLASSIFICATION

APPLYING TO HIGH SPEED TOOL STEEL AND SOME SPECIAL GRADES OF ALLOY TOOL STEEL

Intermediate sizes take the next higher extra
All dimensions inclusive

Round, Square and Octagon

5/8 to 2 inches .... Base

Inches	Extra per lb. Cents
2 1/8 to 2 1/2	2.0
2 5/8 to 3	2.5
3 1/8 to 3 1/2	3.0
3 5/8 to 4	3.5
4 1/8 to 4 1/2	4.0
4 5/8 to 5	4.5
5 1/8 to 5 1/2	5.0
5 5/8 to 6	5.5
6 1/8 to 6 1/2	6.0
6 5/8 to 7	6.5
9/16 to 1/2	2.0
7/16 to 3/8	3.5
5/16 to 11/32	6.0
1/4 to 9/32	8.5

Flat

5/8 to 2 inches thick x 5/8 to 2 inches wide .... Base

Inches	Extra per lb. Cents
1/8 x 3/16	40.0
1/8 x 1/4	30.0
1/8 x 5/16	20.0
1/8 x 3/8 to 2	14.0
3/16 x 1/4 to 3	14.0
1/4 x 5/16 to 1/2	8.0
1/4 x 9/16 to 1	5.0
1/4 x 1 1/8 to 4	3.0
5/16 x 3/8 to 5/8	5.0
5/16 x 3/4 to 1	3.5
5/16 x 1 1/8 to 4 1/2	3.0
3/8 x 7/16 to 3/4	3.0
3/8 x 7/8 to 1 1/2	3.0
3/8 x 1 5/8 to 5	2.5
7/16 x 1/2 to 1	3.0
7/16 x 1 1/8 to 5 1/2	2.5
1/2 x 5/8 to 1	2.5
1/2 x 1 1/8 to 6	2.0
9/16 x 5/8 to 1	2.5
9/16 x 1 1/8 to 6	2.0
5/8 to 2 x 2 1/8 to 4	2.0
5/8 to 2 x 4 1/8 to 7	4.0
2 1/8 to 3 x 2 1/8 to 4	2.0
2 1/8 to 3 x 4 1/8 to 7	4.0

Annealing

	Cents per lb.
Annealing Tungsten Steels	2

TUNGSTEN-STEEL CLASSIFICATION

(Continued)

Cutting to Specified Single and Multiple Lengths

	Extra per lb. Cents
24 inches and over	1
18 to 23 15/16 inches	2
12 to 17 15/16 inches	3
6 to 11 15/16 inches	4

Less than 6 inches, special prices.
Minimum cutting charge, 25 cents.

Forged Disc Classification

Weighing	Extra per lb. Cents
Above 25 lbs	6
15 to 25 lbs	10
10 to 15 lbs	12
7½ to 10 lbs	14
5 to 7½ lbs	16
3 to 5 lbs	18
2 to 3 lbs	22
1 to 2 lbs	24

Under 1 lb., special price.
Annealing, 2 cents per lb. extra.

Forged Die Block Classification

Weighing	Extra per lb. Cents
Above 25 lbs	4
15 to 25 lbs	6
10 to 15 lbs	10
7½ to 10 lbs	14
5 to 7½ lbs	16
3 to 5 lbs	18
2 to 3 lbs	22
1 to 2 lbs	24

Under 1 lb., special price.
Annealing, 2 cents per lb. extra.

Forged Ring Classification

Prices upon application.

DISCS — DIE BLOCKS — RINGS

LUDLUM TOOL STEEL DISCS can be furnished in any of our standard grades of carbon, alloy and high speed steels and will meet the needs of the most exacting customer. Our warehouse facilities assure prompt shipment of stock sizes from the nearest point possible.

Customers are requested to state whether forged discs are required, or whether it will be satisfactory to have us supply discs sawed from round bars of the required size.

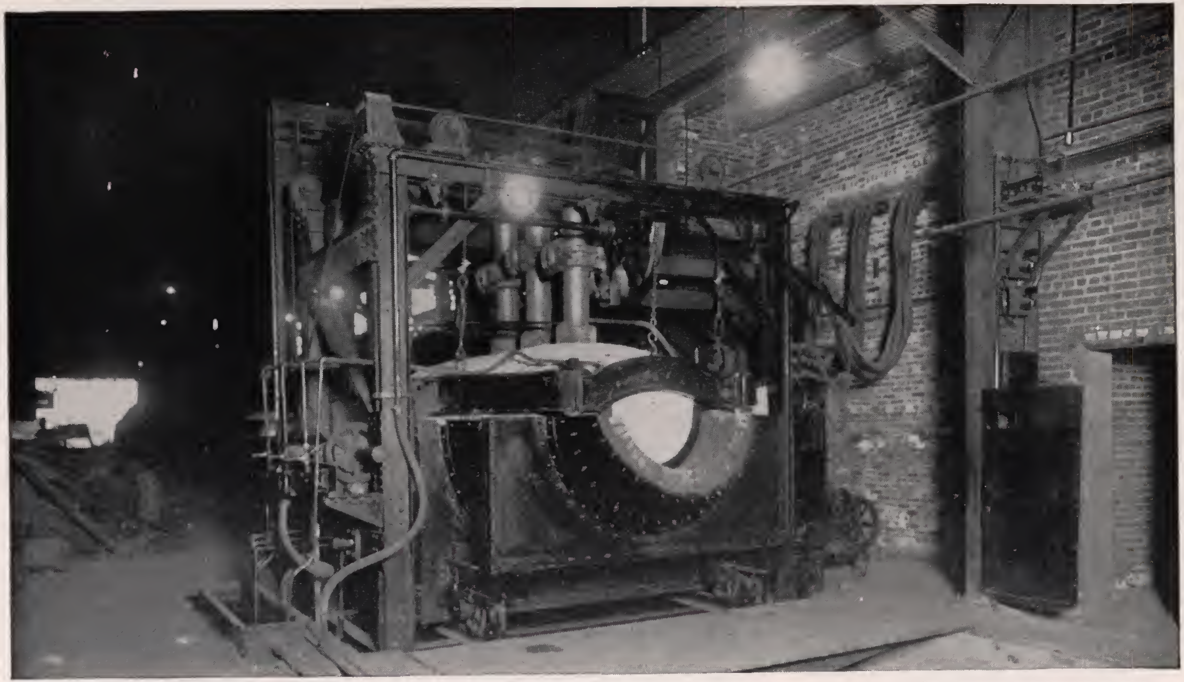
On the preceding pages will be found lists showing the standard extras that apply to carbon and high speed forged tool steel discs. To obtain the pound price of any disc, add the disc extra, for the given weight, to the base price per pound of steel desired; for sawed discs, add merely the regular bar extra for size plus the cutting charge.

LUDLUM DIE BLOCKS can be furnished in any of our straight carbon steels and in a number of alloy steels. We will be glad to suggest the compositions which we consider best suited for the use intended; the nature of work turned out, the quantity of output desired, and the amount of labor expended in making the die, being important factors taken into consideration.

Forged die blocks take the extras given on the preceding pages over and above the regular base price of the steel from which they are made.

LUDLUM TOOL STEEL RINGS can be supplied in all our standard grades of carbon, alloy and high speed steel. Prices will be quoted upon receipt of specifications, and our metallurgical department will at all times give any desired assistance in the selection of the most suitable analysis for the purpose.

SPECIAL NOTE—*In ordering discs, die blocks or rings, customers should specify overall, not finished, dimensions, as we make no allowances for finishing.*



Ludlum Electric Crucible Furnace. The first movable bottom type in the world. Perfected and used exclusively by The Ludlum Steel Co.

ALLOYS
and their effect upon
STEEL

NICKEL
CHROMIUM
NICKEL CHROMIUM

CHROMIUM-VANADIUM
MANGANESE
TUNGSTEN

MOLYBDENUM
CHROMIUM-SILICON
SILICON

NICKEL

NICKEL may be considered as the toughest among the non-rare alloys now used in steel manufacture. Originally nickel was added to give increased strength and toughness over that obtained with the ordinary rolled structural steel, and little attempt was made to utilize its great possibilities so far as heat treatment was concerned.

The difficulties experienced have been a tendency towards laminated structure during manufacture and great liability to seam, both arising from a non-homogeneous melt. When extra care is exercised in the manufacture, particularly in the melting and rolling, many of these difficulties can be overcome.

The electric steel furnace, of modern construction, is a very important step forward in the melting of nickel steel; neither the crucible process nor the basic or acid open hearth furnaces give such good results. It is also necessary that small ingots be made so as to cut down undue piping.

In rolling, great care must be exercised in reheating the billet so that the steel is correctly soaked, and the rolling must not be forced; too big reductions per pass should not be indulged in as these set up a tendency towards seams.

Nickel steel has remarkably good mechanical qualities when suitably heat-treated, and it is pre-eminently adapted for case hardening. It is not difficult to machine low nickel steel; therefore it is in great favor where easy machining properties are of importance.

Nickel influences the strength and ductility of steel by being dissolved directly in the iron or ferrite, in this respect differing from chromium, tungsten and vanadium. The addition of each 1% nickel up to 5% will cause an approximate increase of from 4,000 to 6,000 pounds per square inch in the tensile strength and elastic limit over the corresponding

carbon steel and without any decrease in ductility. The static strength of nickel steel is affected, to some degree, by the percentage of carbon; for instance steel with .25% carbon and 3.5% nickel has a tensile strength, in its normal state, equal to a straight carbon steel of .5% with a proportionately greater elastic limit and retaining all the advantages of the ductility of the lower carbon.

To bring out the full qualities of nickel steel it must be heat-treated, otherwise there is no object in using nickel as an alloy in carbon steel; the additional cost is not justified by increased strength.

Nickel has a peculiar effect upon the critical ranges of steel, the critical range being lowered by the percentage of nickel; in this respect it is similar to carbon only more marked. Generally speaking, nickel steel requires a lower heat-treating temperature than chrome steel or tungsten steel, and in this respect is very similar to manganese.

Nickel can be alloyed with steel in various percentages, each percentage having a very definite effect on the micro-structure. For instance, a steel with .2% carbon and 2% nickel has a pearlitic structure, but the grain is much finer than if the straight carbon were used. With the same carbon content and say 5% nickel, the structure would still be pearlitic, but much finer and denser, therefore capable of withstanding shock and having greater dynamic strength. With about .2% carbon and 8% nickel, the steel is nearing the stage between Pearlite and Martensite, and the structure is extremely fine, the Ferrite and Pearlite having a tendency to orientate, as seen in a purely Martensite structure. .2% carbon with 15% nickel is entirely Martensite. Higher percentages of nickel change the Martensite structure to Austenite, the steel then being non-magnetic.

To obtain the full effect of nickel as an alloy, it is essential that the correct percentage of carbon be used. High nickel

and low carbon will not be more efficient than lower nickel and higher carbon, but the cost will be much greater. Generally speaking, heat-treated nickel alloy steels are about 2 to 3 times stronger than the same steel annealed. This point is very important, as many instances have arisen where nickel steel is incorrectly used, being employed when in the annealed or normal state.

CHROMIUM

CHROMIUM when alloyed with steel has the characteristic function of opposing the disintegration and reconstruction of Cementite. This is demonstrated by the changes in the critical ranges of this alloy steel taking place slowly; in other words, it has a tendency to raise the Ac range (decalescent points) and lower the Ar range (recalescent points). Chromium steels are therefore capable of great hardness, due to the rapid cooling being able to retard the decomposition of the Austenite.

The great hardness of chromium steels is also due to the formation of double carbides of chromium and iron. This condition is not removed when the steel is slightly tempered or drawn. This additional hardness is also obtained without causing undue brittleness such as would be obtained by any increase of carbon. The degree of hardness of the lower chrome steels is dependent upon the carbon content, as low chromium alone will not materially harden iron.

The toughness so noticeable in this steel is the result of the fineness of structure; in this instance the action is similar to that of nickel, and the tensile strength and elastic limit are therefore increased without any loss of ductility. We then have the desirable condition of tough hardness, making chrome steels extremely valuable for all purposes requiring great

resistance to wear, and in higher chrome contents resistance to corrosion. All chromium alloy steels offer great resistance to corrosion and erosion. In view of this, it is surprising that chromium steels are not more largely used for structural steel work and for all purposes where the steel has to withstand the corroding action of air and liquids. Bridges, ships, steel buildings, etc., would offer greater resistance to deterioration through rust if the chromium alloy steels were employed.

Prolonged heating and high temperatures have a very bad effect upon chromium steels, and in this respect they differ from nickel steels, which are not so affected by prolonged heating, but chromium steels will stand higher temperatures than nickel steels when the period is short.

Chromium steels, due to their admirable property of increased hardness without the loss of ductility, make very excellent chisels and impact tools of all types, although for die blocks they do not give such excellent results as can be obtained from other alloy combinations.

For ballbearing steels, where intense hardness with great toughness and ready recovery from temporary deflection is required, chromium as an alloy offers the best solution.

Two per cent chromium steels, due to their very hard, tough surface, are largely used for armour piercing projectiles, cold rolls, crushers, drawing dies, etc.

The normal structure of chromium steels with a very low carbon is roughly pearlitic up to 7 per cent and martensitic from 8 to 20 per cent, therefore the greatest tool steel application is in the pearlitic zone or the lower percentages. Special steels having remarkable wear resisting properties are made from chromium steel in the martensitic zone with about 12 per cent of chromium and very high carbon. Rustless steels contain about the same chromium with low or high carbon and high silicon.

NICKEL-CHROMIUM

A combination of the characteristics of nickel and the characteristics of chromium, as described, should obviously offer a very excellent steel, as the nickel particularly affects the ferrite of the steel and the chromium, the carbon. From this combination we are able to get a very strong ferrite matrix and a very hard, tough Cementite. The strength of a strictly pearlitic steel over a pure iron is due to the pearlitic's being a layer arrangement of Cementite running parallel to that of a pure iron layer in each individual grain. The ferrite, i. e., the iron, is increased in strength by the resistance offered by the Cementite which is of the stable iron carbon combination or carbide known as Fe_3C. The Cementite, although adding to the tensile strength, is very brittle, and the strength of the pearlite is the combination of the ferrite and Cementite. In the event of the Cementite's being strengthened, as in the case of strictly chromium steels, an increased tensile strength is readily obtained without loss of ductility, and if the ferrite is strengthened, then the tensile strength and ductility of the metal is still further improved.

The Nickel chromium alloy represents one of the best combinations available at the present time. The nickel intensifies the physical characteristics of the chromium, and the chromium has a similar effect on the nickel.

For case hardening, nickel chromium steels seem to give very excellent results. The carbon is very rapidly taken up in this combination, and for that reason this combination is rather preferable to the straight nickel steel.

With the mutually intensifying action of chromium and nickel there is a most suitable ratio for these two alloys, and it has been found that roughly 2½ parts of nickel to about 1 part of chromium gives the best results. Therefore, we have the standard types of 3.5% nickel—1.5% chromium,

1.5% nickel—.6% chromium and the various intermediary types. This ratio, however, does not mean the whole story of nickel chromium combinations, and many surprising results have been obtained with these alloys when other percentage combinations have been employed.

CHROMIUM-VANADIUM

Much has been stated and published concerning vanadium as an alloy with chromium and the benefits to be derived from chrome vanadium steel over and above those obtainable from chromium nickel.

Vanadium has a very marked effect upon alloy steels rich in chromium, carbon or manganese. Vanadium itself, when combined with steel very low in carbon, is not so noticeably beneficial as the same carbon steel higher in manganese, but if a small quantity of chromium is added, then the vanadium has a very marked dynamic effect. Therefore it would seem that vanadium has the effect of intensifying the action of chromium and manganese, or that vanadium is intensified by the action of chromium or manganese.

Vanadium has the peculiar property of readily combining with the ferrite and also with the carbon, forming carbides, and is to be found in solid solution in the ferrite. The ductility of carbon vanadium steels is therefore increased, likewise the ductility of chrome vanadium steels.

The full effect of vanadium is not felt unless the temperatures, to which the steel is heated for hardening, are raised considerably; therefore it is necessary that a certain amount of soaking takes place so as to get the necessary equalization. This is true of all cementitic compounds, of which vanadium is one.

Chrome vanadium steels also have a tendency towards

greater depth of hardening and anti-fatigue properties than can be obtained from straight chromium steels. It would appear that the intensification of the chromium and manganese in the alloy steel accounts for this peculiar phenomenon.

Vanadium is also a very excellent scavenger either for removing the harmful gases or causing them to enter into solution with the metal in such a way as largely to obviate their harmful effects. Chrome vanadium steels have been claimed by many steel manufacturers and users to be preferable to nickel chrome steels. While not wishing to pass judgment on this, it should be borne in mind that the chrome vanadium steel which is tested is generally compared with a very low nickel chromium alloy steel (the price factor entering into the situation), but equally good results can be obtained by nickel chromium steels of suitable analysis.

Where price is the leading factor, many instances are arising where a stronger steel can be obtained from the chrome vanadium than the nickel chromium. It will be safe to say that each of these two systems of alloys has its own particular fields, and chrome vanadium steel should not be regarded as the sole solution for all problems, nor should nickel chromium.

MANGANESE

Manganese adds considerably to the tensile strength of steel, but is dependent on the carbon content. High carbon materially adds to the brittleness, whereas low carbon, pearlitic, manganese steels are very tough and ductile and are not at all brittle, providing the heat-treating is correct.

Manganese steel is very susceptible to high temperatures and prolonged heating.

Low carbon, pearlitic, manganese steel is a very efficient steel, but its efficiency is entirely dependent on the temperature to which it is heated for hardening or the tem-

perature used for annealing. Low carbon, pearlitic, manganese steel made in the electric furnace seems to be more efficient than the same chemical analysis steel made by either the open hearth or crucible process. No reason has, as yet, been assigned for this peculiar phenomenon, but it is believed that the removal of the harmful gases, particularly oxygen and nitrogen, is responsible.

Manganese when added to steel has the effect of lowering the critical range; 1% manganese will lower the upper critical point 60 degrees F. The action of manganese is very similar to that of nickel in this respect, only twice as powerful; as an instance, 1% nickel would have the effect of lowering the upper critical range from 25 degrees to 30 degrees F.

Low carbon, pearlitic, manganese steel, heat-treated, will give dynamic strength which cannot be equalled by low-priced, and necessarily low content, nickel steels. In many instances it is preferable to use high grade manganese steel, rather than low content nickel steel.

High manganese steels, or Austenitic manganese steels, are used for a variety of purposes where great resistance to abrasion is required, the percentage of manganese being from 11 to 14 per cent, and carbon 1 to 1.50 per cent. This steel is practically valueless unless heat-treated; that is, heated to about yellow red and quenched in ice water. The structure is then Austenite, and the air cooled structure of this steel is Martensite. Therefore, this steel has to be heated and very rapidly cooled to obtain the ductile Austenite structure.

Manganese between 2 and 7 per cent is a very brittle material when the carbon is about 1 per cent or higher, therefore quite valueless. Below 2 per cent, manganese steel low in carbon is very ductile and tough steel.

The high content manganese steels are often known as the "Hadfield manganese steels," having been largely developed

by Sir Robert Hadfield. Small additions of chrome up to 1 per cent increase the elastic limit of low carbon, pearlitic, manganese steels without affecting the steel in its resistance to shock, but materially decrease the percentage of elongation.

Vanadium, added to low carbon, pearlitic, manganese steel, has a very marked effect, increasing greatly the dynamic strength and changing slightly the susceptibility of this steel to heat treatments, giving a greater margin for the hardening temperature. Manganese steel with added vanadium is most efficient when heat-treated.

TUNGSTEN

TUNGSTEN, as an alloy in steel, has been known and used for a long time, the celebrated and ancient Damascus steel being a form of tungsten alloy steel. Tungsten and its effects, however, did not become generally realized until Robert Mushet experimented and developed his famous Mushet steel, and the many improvements made since that date go to prove how little Mushet himself understood the peculiar effects of tungsten as an alloy.

Tungsten acts on steel in a similar manner to carbon, that is, it increases its hardness, but is much less effective than carbon in this respect. If the percentage of tungsten and manganese is high, the steel can be hardened by cooling in the air. This effect is directly opposite to that of carbon. It was this combination that Mushet used in his well known steel.

The principal use of tungsten is in high speed tool steel, but here a high percentage of manganese is distinctly detrimental, making the steel liable to fire crack, very brittle and weak in the body and less easily forged and annealed. Manganese should be kept low, and a high percentage of chromium used instead.

The tungsten-chromium steels, when hardened, retain their hardness even when heated to a dark cherry red by the friction of the cutting or the heat arising from the chips. This characteristic led to the term red hardness being applied to this class of steel, and it is this property that is responsible for the increase of cutting speeds in the tungsten chrome alloy, that is, high speed steel.

Tungsten when added to steel up to 6% does not have the property of red hardness any more than carbon tool steel, providing the manganese or chromium is low. Tungsten has a rapidly increasing cutting efficiency up to about 18 per cent, more than this is not desirable. Above 5 to 6 per cent tungsten, chromium must be employed to get good results.

If chromium is alloyed with tungsten, then a very definite red hard effect is noticed with a great increase in cutting efficiency. The maximum red hard cutting efficiency of the tungsten chrome steel seems to be a definite chemical-analysis ratio, but there are various mechanical and other reasons why this ratio is not used for high speed steel, as high chromium content steel is very easily spoiled by the high heats necessary in its heat-treatment.

Very little is known of the actual function of tungsten, although a vast amount of experimental work has been done. It is possible that when the effect of tungsten with iron carbon alloys is better known, a greater improvement can be expected from these steels. Tungsten has been tried, and is still used, by some steel manufacturers for making punches, chisels, and other impact tools. Particularly good examples of this are our well known Utica, Seminole and Seneca steels. It has also been used for springs and has given very good results, although other less expensive alloys give equally good results, and in some instances, better.

Tungsten is largely used for permanent magnets. In this

its action is not well understood. In fact, the reason why steel becomes a permanent magnet is not at all understood. Theories have been evolved, but all are open to serious questioning. The principal effect of tungsten, as conceded by leading authorities, is that it distinctly retards separation of the iron carbon solution, removing down to atmospheric temperature the lowest recalescent point.

A peculiar property of tungsten when used in the iron carbon alloys is that when a temperature of 1750°F. is not exceeded, it does not interfere with the carbide change, thereby affecting the temperatures of the recalescent points; whereas when the hardening temperature is raised above 1850°F., a most remarkable effect is conveyed upon the falling transformation points, preventing their formation entirely, down to about atmospheric temperature.

The lowering of the carbide change, which is produced by heating tungsten steels to over 1850°F., and is the real cause of the red hard properties of these alloys, is not understood, and there is no direct evidence to show what actually happens at these high temperatures.

There is every reason to believe that when tungstide Fe_2W is present, it gradually goes into solution as the temperature is raised above 1550°F., the amount of compound present being higher as the tungsten is increased. When completely in solution, the temperature of the carbide change (recalescent point) is lowered on cooling. It is quite an open question, however, whether this lowering is entirely due to the Fe_2W in solution, or whether some other chemical change also occurs.

At a temperature above 1850°F., there may be chemical reactions between the iron and tungsten carbide, which give a new compound resulting in the disappearance of the critical

point at the falling temperature 1300°F. and the appearance of another point at a lower temperature.

Other combinations, in which there should be no free tungstide of iron, give the same lowering of the carbide change after heating to high temperatures; therefore the subject is still surrounded with a fair amount of uncertainty.

MOLYBDENUM

MOLYBDENUM as an alloy in steel has been tried out about as thoroughly as tungsten. The properties of both elements are very similar as far as their effect upon steel is concerned.

Molybdenum imparts hardness to carbon steel by combining with the carbon and alloying to some extent with the iron. Molybdenum has great affinity for carbon, hence it is a carbide forming element. If the steel is of high carbon, the molybdenum is to be found almost entirely with the carbon in the form of carbides, therefore the good properties of molybdenum can only be realized by heat-treatment which will hold the dissolved carbide in solution. Should the carbon of the steel be low, the excess molybdenum over that as carbide is dissolved in the iron, hence low carbon steels, or structural steels, are mostly benefited by the molybdenum additions. High percentages of molybdenum have been used in tool steel, but have not been very successful unless some other element has been used as a carrier or stabilizer of the molybdenum.

The usual stabilizing elements for carrying molybdenum are cobalt and vanadium, but we have found that silicon is a superior carrier or stabilizer for molybdenum; and when chromium is alloyed with molybdenum and silicon, very remarkable steels can be produced.

An instance of this is our Purple Cut; it represents a very interesting example of such a combination. A comparatively

small percentage of chromium, silicon and molybdenum with high carbon will, for some tool purposes, such as threading tools, taps, reamers and finishing cutters, outlast and outcut high speed steel, although for heavy duty work, such as a lathe tool, the high speed steel is far superior.

A lathe tool could be raised to a red temperature, if cutting at high speed, without loss of cutting efficiency. Purple Cut would lose its hardness by being heated beyond a purple heat. It is rare indeed, however, that the cutting edges of a threading tool are ever raised to a temperature higher than a purple heat. Our Purple Cut combination of chrome silicon and molybdenum steel is as hard as high speed steel and more edge-retaining at temperatures under a purple heat.

Molybdenum, even with the more generally recognized stabilizers of cobalt and vanadium, suffers from the serious difficulty of being easily volatilized at rolling temperatures, giving off a characteristic yellow vapor. The easy volatilization of molybdenum is probably responsible for many of the non-uniform results with which molybdenum tool steels are accredited.

Silicon as a carrier or stabilizer seems to prevent volatilization, making molybdenum stable and not prone to failure. Our researches and large applications of this steel to date have shown that silicon apparently has obviated this form of difficulty. Although molybdenum volatilizes during rolling, there does not seem to be much tendency for the molybdenum to be oxidized during remelting. Apparently temperatures play an important part in the volatilization or loss of molybdenum.

Molybdenum increases the elastic limit of structural steels of low or medium carbon and maintains the elastic limit at a high value, even though the ultimate strength is reduced by drawing temperatures. It also adds considerably to the

dynamic strength or shock resistance of the steel. Molybdenum .30–.40% seems to be desirable for this class of steel. In practice it has been shown that molybdenum works very well indeed in conjunction with nickel, chromium and tungsten, besides its recognized carriers or stabilizers, vanadium and cobalt.

CHROMIUM-SILICON

At one time chromium and silicon were used as an alloy spring steel with the silicon about 1%, but this steel did not come into general use, silicon being thought unreliable. Our recent investigations have, however, shown that the principal trouble with silicon when alloyed with chromium, or chromium and molybdenum, has been popular prejudice. Silicon when incorrectly alloyed with iron and carbon produces brittleness, but when alloying elements such as chromium, molybdenum, and nickel, are employed, the silicon adds materially to the toughness, easy workability and reliability of the steel.

The usual straight chromium steel of high or low chromium content carries the chromium in the form of carbide if there is sufficient carbon. Chromium does not form a chemical compound with the iron, but is present in the alloy, probably in the form of a finely divided mechanical mixture or solution of some undetermined form. If there is sufficient carbon present, all of the chromium will be found in the form of chrome carbide.

If silicon is added to chrome steel of high or low carbon, quite a different story is told. Silicon has a great affinity for chromium or iron, forming a chemical compound known as a silicide—iron silicide or chrome silicide. In this chemical form it is neither chromium nor silicon. The silicides are readily dissolvable in iron, probably forming another chemical

compound, which does not separate out into isolated areas of variable concentrations.

It has been known for a long time that silicon readily dissolves in iron and has never been recognized out of chemical solution with the iron. Areas of high concentration are known as silicides but not silicon. With the use of silicon we are able to use chromium in iron, using the full properties and imparting to the iron properties that are not entirely similar to those of chromium and iron, although in some instances they are somewhat related.

Chrome silicon steels or irons are naturally harder than those low in silicon. They take on a peculiar metalloidal temper, as it were, of their own. They have excellent wear-resisting properties, the surface readily glazing and imparting great surface hardness. This is of infinitesimal thickness and does not detract in anyway from the physical properties of the alloy.

Chrome silicon alloys of high or low carbon are very strong and tough and, unlike alloy steels generally, remain tough as the temperature is raised. Ordinarily, steels lose their toughness as the temperature is raised under a red heat. High chrome silicon steels and irons are the outcome of our extensive researches in rustless steels and irons, and they represent one of the most far-reaching developments in this extremely useful field.

SILICON

Silicon is perhaps one of the most plentiful elements of the earth's surface, its natural form being the oxide, silica. The element, silicon, has a somewhat metallic appearance, being of the same chemical group as carbon and has many similar characteristics. Silicon is not a metal any more than carbon is.

It has long been recognized that silicon increases the physical strength of steel, although imparting so-called brittleness by raising the elastic limit and of a necessity lowering the stretch, i. e., elongation and reduction of area. There are certain outstanding examples of silicon steels which are exceptionally tough, for instance silico-manganese steel, a steel high in silicon but with the usual manganese. We presume the reason it is called silico-manganese steel is to overcome some of the prejudice that goes with silicon.

The element, silicon, holds gas in steel in solution and only takes out the excess gas, hence, although it is considered an excellent deoxidizer, it is only a partial deoxidizer. The gas that is held in the steel has given a great deal of trouble and perhaps is responsible for some of the bad reputation that silicon has had. If silicon is used as an alloy in iron and steel, and treated as an alloy, and not used as an alloy and degasifier combined, it is possible to develop some very interesting and wonderful properties in silicon combination alloy steels.

We believe that future tool steel will contain silicon as an alloying element.

Ludlum melting shop, ingots poured with machine shop accuracy, machined bed plate for molds and a rail-conveyed ladle.

CARBON and ALLOY TOOL STEEL

ITS COMPOSITION
AND
HEAT TREATMENT

CARBON AND ALLOY TOOL STEEL

ITS COMPOSITION AND HEAT TREATMENT

Much mystery has been created by those partially initiated in the art of tool steel hardening and heat-treatment. As a matter of fact, there are no mysteries as far as the well known phenomenon of hardening and tempering is concerned. This change in steel follows certain predetermined courses, and, providing the fundamental laws governing this process are observed, no difficulties will be experienced, and the entire operation is one of great simplicity, although calling for a considerable amount of care and observation.

The natural state of iron with carbon as an alloy, known as carbon steel, is the normal state, that is, the annealed state. The two factors, heat and time, play very important parts with the result that steel can be found in many different modifications from the hardened condition to the fully annealed.

Carbon steel, when heated to a temperature above its critical range, takes on a certain crystal formation and endeavors to assume another definite crystal formation on cooling. This ultimate or final crystal formation is known as the soft condition, and, providing sufficient time be given for the crystals to arrange themselves, the steel is known as annealed. In the event of this natural arrangement of the crystals being prevented by any cause, we have the various intermediary modifications, such as unannealed steel, hardened steel and tempered steel.

From the above it is obvious that it is essential first to put the steel in its natural or normal condition. This is done by heating the steel slowly and uniformly to a temperature just above its critical point, called the decalescent point, and

allowing the steel to cool very slowly from this temperature. The decalescent point (decalescent or Ac on the rising temperature and recalescent or Ar on the falling temperature) is caused by the rearrangement of the crystal formation of the steel. The uniform heating, which has taken place up to this point, is suddenly halted, the steel being entirely unaffected by external temperatures. When the crystals have taken on their new formation, the temperature continues to rise. This phenomenon, of which there are several scientific theories, is present in all steels, very marked in high carbon steel and less perceptible in low carbon steel, occurring at a temperature variable with the chemical content of the steel. To harden the steel, so that it is in its hardest and toughest condition, the crystal formation of the steel should be fixed as soon as this rearrangement of crystals has taken place. This is best done by immediately quenching the steel at this temperature.

In the event of the temperature of the steel's being raised above the decalescent point, the crystals in their new formation start to enlarge, and if the tool is chilled or fixed at the higher temperature, then the steel will have a larger grain and be correspondingly weak; this is known among steel men as being "overheated;" if the temperature is still higher, then "burnt".

The overheated steel can be reclaimed by being heated again to the correct temperature and allowed to cool slowly from this critical point; then reheated to just above the decalescent point and quenched in the usual way. The steel is now refined and almost as good as before. In the event of the steel's being "burnt," then it is impossible for any subsequent heat treatment to redeem this steel, and it should be immediately scrapped. The critical temperature or decalescent point (Ac 2.3) has certain magnetic characteristics. That is, when raised to this temperature, through the process of the

rearrangement of the crystals, the steel is not affected by magnetism and is known as non-magnetic. This point, although a parallel with the hardening temperature has nothing to do with it, but serves a very useful purpose in enabling the tool steel hardener to determine the correct hardening temperature for any given carbon tool steel (not alloy tool steel) when lacking the necessary equipment for easily locating the decalescent point.

All tool steels should be tested so as to determine the correct hardening temperature. This can be very easily accomplished, either by taking note of the lowest temperature at which the steel is non-magnetic, or by taking a piece of the tool steel and nicking the bar in a number of places, say 7 nicks about 1″ apart, raising the temperature at one end of the bar until the steel is a light yellow heat, the other end being a black heat, noting the temperature of the sections between the nicks, then chilling the whole in water, preferably at 65°F.

The bar should be carefully dried and each of the sections broken off at the nicks by a sharp blow of the hammer. Each section at the nick has a different grain. The end of the bar which had been overheated will have a very coarse, bright, open grain. This grain will gradually get finer and less fiery until the grain appears to be very fine and of a velvety nature. The next immediate section beyond this will have the same fine velvety nature on the outside, but the center will appear coarse. The temperature at this point is too low, and the one section higher where the grain is fine and velvety throughout is the correct hardening temperature.

Many tool hardeners are under the impression that to make steel very hard it is necessary to harden at an increasingly high temperature. This is incorrect, as the increased hardness conveyed to the steel by quenching at excessive tem-

peratures is very small (in some cases the steel is actually softer), and the strength of the steel which is necessary to maintain the cutting edge or resistance to compression, etc., diminishes at a very quick rate.

The correct hardening temperature for carbon tool steels is the lowest temperature at which the steel will harden.

All tool steels should be tempered slightly to remove the strains, and to impart to the steel great toughness.

HIGH SPEED TOOL STEEL

INSTRUCTIONS FOR

FORGING
ANNEALING
HARDENING
TEMPERING

MILLING CUTTERS AND SHAPE TOOLS

LATHE AND PLANER TOOLS

Extreme care is necessary in the re-heating of tool-steel ingots.

INSTRUCTIONS FOR WORKING HIGH SPEED STEEL

Cutting-Off.—To cut a piece from an annealed bar, cut off with a hack saw, milling cutter or circular saw. Cut clear through the bar; do not nick or break. To cut a piece from an unannealed bar, cut right off with an abrasive saw; do not nick or break. If of large cross-section, cut off hot with a chisel by first slowly and uniformly heating the bar, at the point to be cut, to a good lemon heat, 1800°–1850°F. and cut right off while hot; do not nick or break. Allow the tool length and bar to cool before reheating for forging.

LATHE AND PLANER TOOLS

Forging.—Gently warming the steel to remove any chill, is particularly desirable in the winter. Then heat slowly and carefully to a scaling heat, that is, a lemon heat (1800°–2000°F.), and forge uniformly. Reheat the tool for further forging directly the steel begins to stiffen under the hammer. Under no circumstances forge the steel when the temperature falls below a dark lemon to an orange color about 1700°F. Reheat as often as is necessary to finish forging the tool to shape. Allow the tool to cool after forging by burying in dry ashes or lime. Do not place on the damp ground or in a draught of air.

The heating for forging should be done preferably in a pipe or muffle furnace, but if this is not convenient, use a good clean fire with plenty of fuel between the blast pipe and the tool. Never allow the tool to soak after the desired forging heat has been reached. Do not heat the tool further back than is necessary to shape the tool, but give the tool sufficient heat. See that the back of the tool is flatly dressed to provide proper support under the nose of the tool.

Hardening.—Slowly reheat the cutting edge of the tool to a cherry red, 1400°F., then force the blast so as to raise the temperature quickly to a full white heat, 2200°–2250°F., that is, until the tool starts to sweat at the cutting face. Cool the point of the tool in a dry air blast, or preferably in oil, further cool in oil, keeping the tool moving until it has become black hot.

Tempering.—To remove hardening strains reheat the tool to from 500° to 1100°F. Cool in oil or atmosphere. This second heat treatment adds to the toughness of the tool and therefore to its life.

Grinding.—Grind tool to remove all scale. Use a quick cutting, dry, abrasive wheel. If using a wet wheel, be sure to use plenty of water. Do not under any circumstances force the tool against the wheel so as to draw the color, as this is likely to set up checks on the surface of the tool to its detriment.

MILLING CUTTERS AND SHAPE TOOLS

Forging.—Forge as before.

Annealing.—Place the steel in a pipe, box or muffle. Arrange the steel so as to allow at least 1″ of packing, consisting of dry powdered ashes, powdered charcoal, mica, etc., between the pieces and the walls of the box or pipe. If using a pipe, close the ends. Heat slowly and uniformly to a cherry red, 1375°–1450°F. according to size. Hold the steel at this temperature until the heat has thoroughly saturated through the metal, then allow the muffle box and tools to cool very slowly in a dying furnace, or remove the muffle with its charge and bury in hot ashes or lime. The slower the cooling, the softer the steel.

The heating requires from 2 to 10 hours, depending upon the size of the piece.

Hardening and Tempering.—It is preferable to use two furnaces when hardening milling cutters and special shape tools. One furnace should be maintained at a uniform temperature from 1375° to 1450°F. while the other should be maintained at about 2250°F. Keep the tool to be hardened in the low temperature furnace until the tool has attained the full heat of this furnace. A short time should then be allowed so as to be assured that the center of the tool is as hot as the outside. Then quickly remove the tool from this preheating furnace to the full heat furnace. Keep the tool in this furnace only as long as is necessary for the tool to attain the full temperature of the furnace. Then quickly remove and quench in oil or in a dry air blast. Remove before the tool is entirely cold and draw the temper in an oil bath by raising the temperature of the oil to from 500° to 750°F. Allow the tool to remain at this temperature in the bath for at least 30 minutes, insuring uniformity of temper; then cool in the bath, atmosphere or oil.

If higher drawing temperatures are desired than those possible with oil, a salt bath can be used. A very excellent bath is made by mixing two parts by weight of crude potassium nitrate and three parts crude sodium nitrate. These will melt at about 450°F. and can be used up to 1000°F. Before heating the steel in the salt bath, slowly preheat, preferably in oil. Reheating the hardened high speed steel to 1000°F. will materially increase the life of lathe tools, but milling and form cutters, taps, dies, etc., should not be reheated higher than 500° to 650°F.

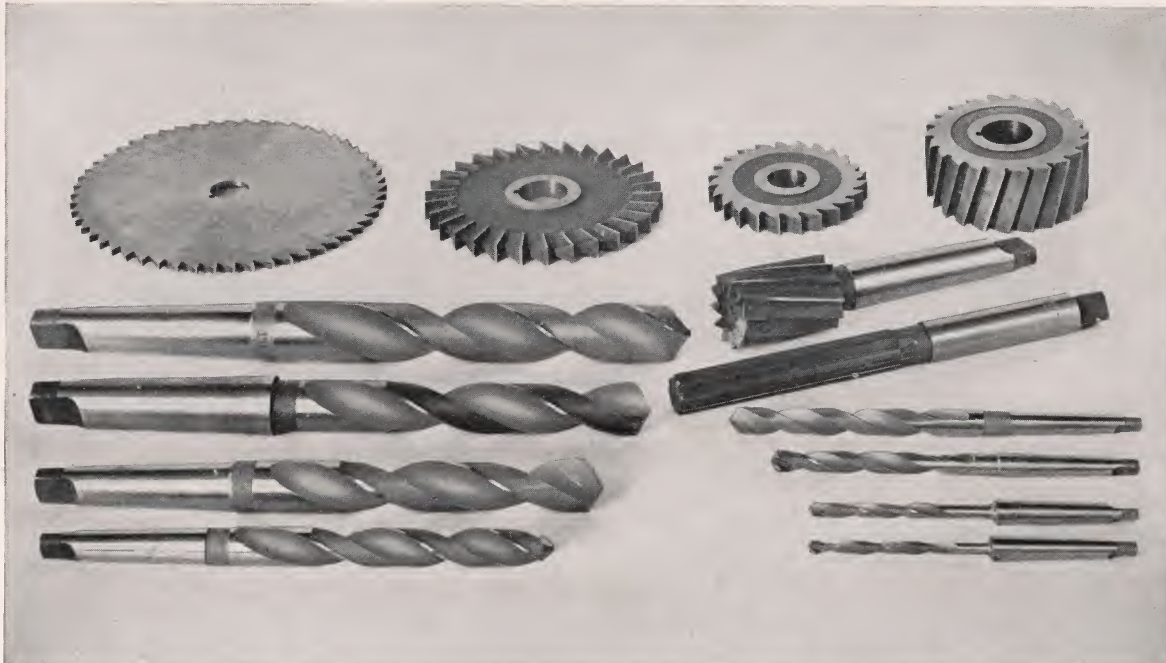
View of rolling-mill building showing one of our finishing mills in the foreground.

LUDLUM
HIGH SPEED
STEEL

MOHAWK EXTRA

MOHAWK EXTRA
TOOL-HOLDER BITS

MOHAWK
HOT WORK DIE STEEL



Cutters and drills made of Mohawk Extra high speed steel.

MOHAWK EXTRA

HIGH SPEED STEEL

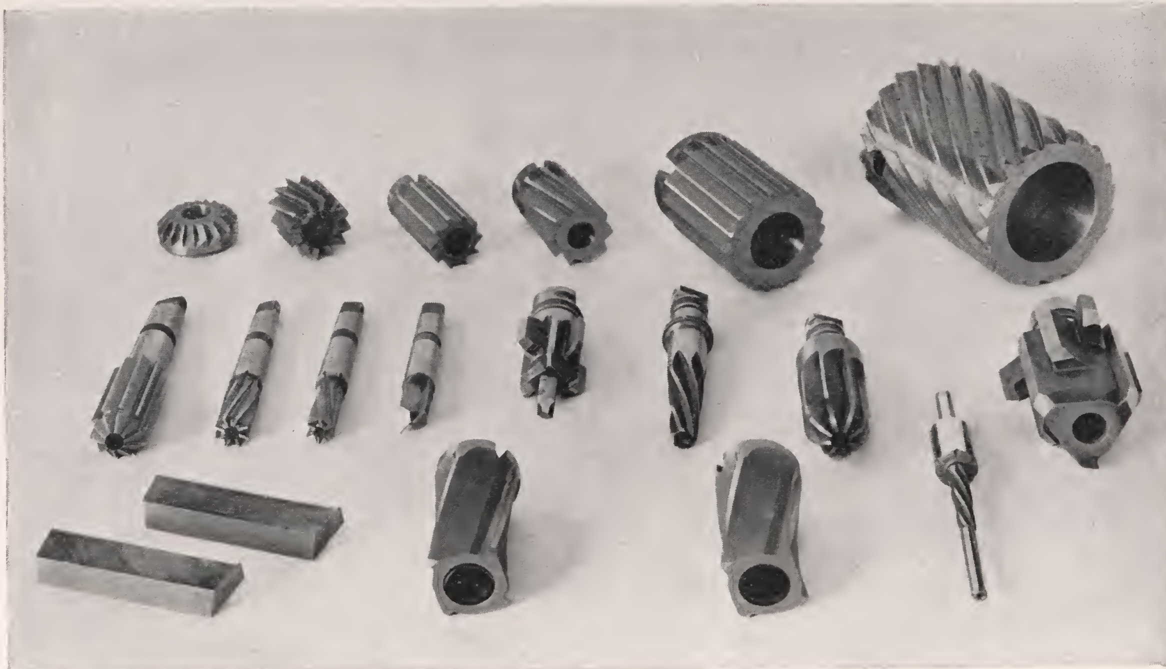
Mohawk Extra represents the latest developments in electro-metallurgy. It is consistently uniform, is designed to withstand the most exacting demands of high duty machine tools and will stand very high speeds and heavy cuts and low speeds and heavy cuts. It is quite unexcelled for turning toughened alloyed steels and will work at a red heat for a long period without the edge failing. It is particularly adapted for taps and dies, twist drills, milling cutters and reamers; it can be readily forged, and is particularly free from any tendency to check and crack when being hardened. It will carry a very keen edge and is an excellent finishing steel.

Mohawk Extra can be readily annealed; therefore it is very economical when being machined to shape. This steel is remarkable for its density and homogeneity. Where the equipment of the machine shop is not sufficiently powerful to use the full cutting capacity of Mohawk Extra, it is still pre-eminently economical on account of the very long periods this steel can be run without having to be resharpened.

Our Mohawk Extra represents the highest development in high speed steel and is used in very large quantities. It is capable of withstanding the highest cutting load that can be developed on the modern high-duty machine tool. It will stand deeper cuts, greater feeds and higher speed than any other high speed steel made.

We recommend it for lathe, shaper, planer, boring mill tools, milling cutters, form cutters, finishing tools, dies, reamers, and for all purposes where heavy duty cutting or finishing is required. It can be furnished in annealed and unannealed bars, blocks and dies.

HEAT TREATMENT: *See pages* 47–49.



Mohawk Extra is unexcelled for high speed tools of all designs.

MOHAWK EXTRA

HIGH SPEED STEEL TOOL-HOLDER BITS

These tools are made out of our well-known Mohawk Extra High Speed Steel, cut to standard tool-holder lengths with 30-degree angle ends. Each piece is hardened, ready to be ground and put to work.

Furnished from stock in 5-pound, 10-pound, and larger boxes; one size or assorted sizes in a box.

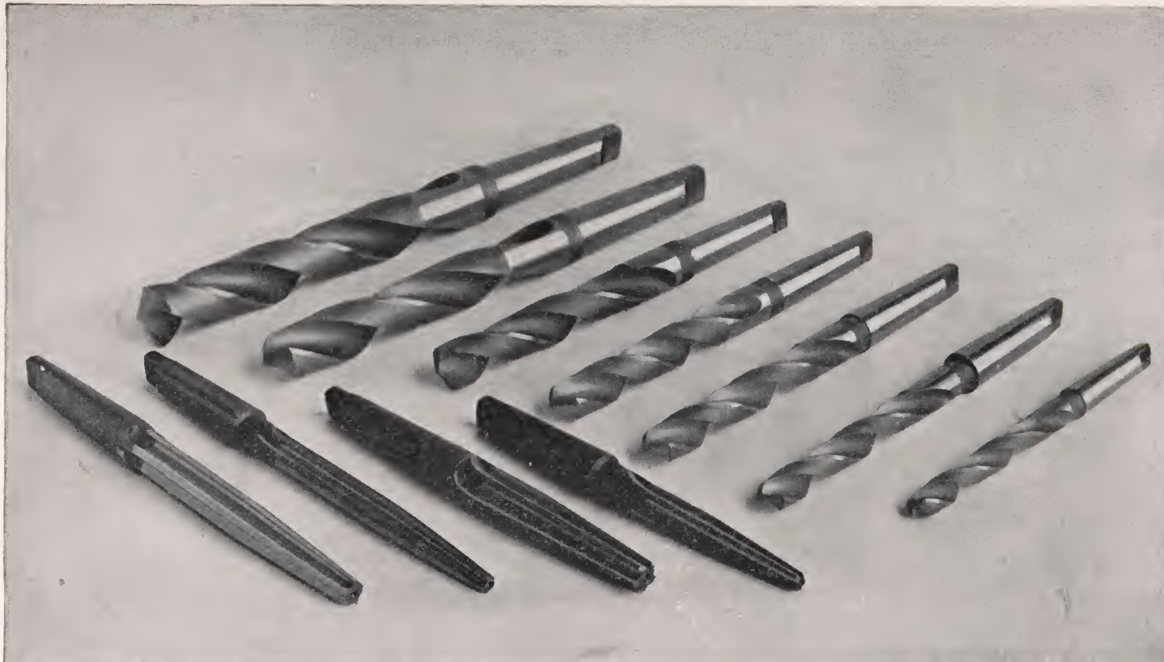
Prices on application.

STANDARD LENGTHS, READY TO SHIP

3/16 inch square,	2½ inches long
¼ inch square,	2½ inches long
5/16 inch square,	2½ inches long
⅜ inch square,	3 inches long
7/16 inch square,	3½ inches long
½ inch square,	4 inches long
⅝ inch square,	4½ inches long
¾ inch square,	5 inches long
⅞ inch square,	6 inches long
1 inch square,	6 inches long

We also carry in 12-inch lengths, for tool-holders, a large assortment of treated squares and flats up to 1 square inch in section.

DIRECTIONS FOR TREATED BARS.—Do not heat to cut, but nick the bar on all four sides upon an emery-wheel; then break cold to desired length and grind to shape on a dry wheel.



Mohawk Extra high speed steel drills and reamers are used extensively.

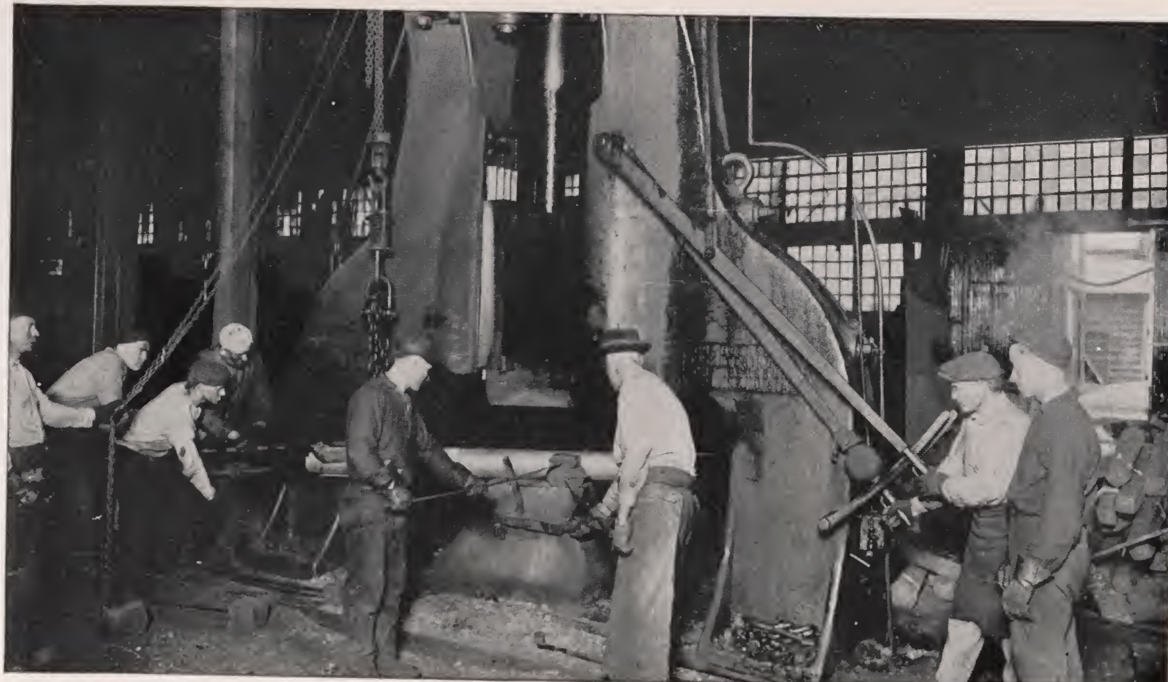
MOHAWK

HOT WORK DIE STEEL

There is a large demand for a steel which will withstand the heating effects of hot work as, for instance, in heading dies, etc. We have developed our Mohawk hot work die steel to meet this demand.

This steel is an air and oil hardening steel that is almost file hard, will not batter up, and is extremely tough. It is not recommended for drop-forge dies, but is intended for rivet making and bolt heading dies, hot punches, tong bits, extrusion dies and hot work generally.

HEAT TREATMENT: *Supplied on request.*



One of the Ludlum Steel Company's battery of hammers.

CARBON and ALLOY TOOL STEEL

INSTRUCTIONS FOR

FORGING
ANNEALING
HARDENING
TEMPERING

INSTRUCTIONS FOR WORKING CARBON AND ALLOY TOOL STEELS

There are three important points to observe in making a successful tool:

1. The correct selection of the grade and carbon of the tool steel.

2. Careful and correct forging.

3. Correct hardening and tempering.

FORGING

FORGING.—Forging should be conducted with the greatest care. The blacksmith should, if his equipment will allow, choose an oil or gas fired muffle furnace as the heating agent in preference to a forge fire because of the ease of the temperature control. However, the forge fire will give very excellent results when proper care is taken. It is essential that a clean fire be used with plenty of fuel between the steel to be heated and the blast nozzle to protect the corners of the piece from the injurious effects of the air blast on the heated metal. Slow heating is very important, and the heating should never be faster than can be uniformly driven through the piece, otherwise the edges and surface of the steel will be overheated. The higher the carbon of the steel, the greater the care to be exercised so as to avoid overheating, burning, or decarbonization.

The blacksmith must never heat the tool back on the shank any further than is absolutely necessary to take care of the forging. This is particularly important when air hardening or alloyed steels are used.

As soon as the piece has reached a uniform forging heat, it should be immediately withdrawn from the fire. Soaking,

or allowing the steel to remain in the fire after it has been uniformly heated through, is extremely injurious. In fact, no practice will more quickly make the steel dry and brittle. Vigorously hammer the steel at the high heat and with constant but more gentle strokes as the heat falls.

The steel should be hammered until the tool is black red, that is, just shows red in the dark. The steel will then have the finest grain possible. Care should be taken not to hammer the steel below this temperature. After forging, the tool should be allowed to cool to black heat and then be reheated to about 1350° to 1400°F., that is, a cherry red heat, and be allowed to cool in a warm place. This will remove all forging strains and refine the grain

ANNEALING

Annealing.—Carbon tool steel that has been well worked under the hammer or in the rolls is generally too hard to be readily machined without first being normalized, that is, annealed or softened. When machining the steel into intricate shapes for tools or dies, the steel must first be annealed and this is easily accomplished by the comparatively simple operation of slowly and uniformly heating the steel to about 1360° to 1400°F. The tool must under no circumstances be allowed to soak at this maximum temperature, but remain at this temperature just as long as is necessary for the steel to be uniformly heated through. The tool should be allowed to cool very slowly. This can be done by leaving the tool in the furnace while it is cooling, or else the tool can be removed from the fire and buried in lime, powdered mica, dry ashes, etc. The tool when cold will be quite soft and readily machinable.

In heating the tool, great care should be taken that it does not come in contact with the air blast and is not subjected to draughts or to unduly oxidizing or carbonizing flames. If the tool to be annealed has been heated in an open fire or muffle

furnace without being packed, the tool on cooling should show the black scale which was on the tool previous to being reheated for annealing. If this surface is disturbed at all it is due to the fire's being dirty or the result of too high a temperature.

It is always advisable in annealing steel to make use of a closed box, a pipe, or a muffle, and to surround the steel with powdered mica, ashes, lime, etc., so as to prevent direct contact with the flame or access of the air. When this preferable method of annealing is adopted and the tool allowed to remain in the packed muffle until cold, the steel on being removed is comparatively free from scale.

In annealing steel it is generally quite impossible to prevent slight surface decarbonization, and this may amount to as much as 1/16" to 1/8". This partial surface decarbonization is often difficult to trace by rough and ready methods; the tool will harden satisfactorily as far as a test by file is concerned, yet the surface of the steel has decarbonized to the extent of .10 to .20 carbon which will result in the failure of the tool.

Provision should always be made to allow for at least 1/8" reduction on the working surface of the steel after annealing. This is to insure the full temper of the steel being present at the cutting edge of the tool. Failure to observe this simple precaution of the removal of the skin, will often result in loss, not only due to a slight decarbonization, but from an excessive decarbonization causing soft spots on hardening.

HARDENING

Hardening.—It is only possible to give general instructions for hardening, as every temper of carbon steel will require slightly different hardening temperatures, and different treatments will be required according to the results desired. The advice herein given for hardening covers the general points in hardening of tempers of carbon tool steel, and they only need be varied to suit the individual case. The operation is

extremely simple, but requires a great deal of care and close attention. Every detail must be carefully watched and noted, otherwise the entire cost of a very valuable die can be irretrievably lost, due to some faulty operation in either the heating or quenching. These details, when carefully noted and observed, render the operation of hardening comparatively simple.

The tool to be hardened should first be normalized to remove any working strains due to machining operations, etc., and to release any strains that may perhaps be left in the steel from forging or faulty annealing. The tool should be slowly warmed through, then slowly heated to a dull red 1360°–1400°F. and allowed to cool in dry lime. The tool when cold, or slightly warm, should be slowly reheated, care having been taken to see that the tool is turned a number of times to insure a uniform heat effect. This can be done best in a lead pot, salt bath, or in an oil or gas fired muffle. If a forge fire is used, care must be taken that there is plenty of fuel between the tool to be heated and the blast nozzle. It is also essential that the blast should be very gentle and the tool be turned over and over so that the heat will be conveyed across the steel in a uniform manner. Immediately the tool has been uniformly heated through, from a dull to a full cherry red, varying with the temper, that is from 1375° to 1500°F., it should be quickly withdrawn from the fire and chilled in the cooling medium. The tool should be agitated, as this will prevent any hardening line occurring and will cool the steel more uniformly.

The quenching medium is preferably good clean water at about 65°F. If a tough center tool is required, water at 80°F. will be found most satisfactory. A brine or acid solution can be used if extreme hardness is required. It is generally better to use a higher temper and quench in cold water rather than to endeavor to get extreme hardness

with a lower temper steel. For slender and irregular shapes it is preferable to quench in oil at about 70° to 85°F. The oils most suitable for this purpose are as in the order named:

New fish oil

Lard oil, 75% plus 25% paraffin

Boiled linseed oil

Raw linseed oil

Extra bleached fish oil

Cotton seed oil

Tempering oil—60% cotton-seed
40% mineral

Mineral oil.

Either of the first three are excellent oils for all purposes of quenching.

Under no circumstances may the steel be quenched from a falling temperature. The temperature must always be rising or stationary. The reason for this is that the grain of the steel on quenching is always the grain of its highest temperature. Therefore, if carbon tool steel is heated, say, to 1600°F. and allowed to fall until it is 1400°F., and then quenched, the steel will be found to have all the characteristics of a steel quenched at 1600°F. The steel will be overheated and comparatively useless.

In the event of the hardener's overheating the steel in this manner, the tool should be allowed to cool until warm, then reheated to the lowest hardening temperature and quenched.

It will be found that the lowest hardening temperature will vary in any one given temper with the size of the piece to be hardened. It might be well to explain the reason for this, as lack of knowledge of this important point has resulted in many misunderstandings and much spoiled steel.

As previously pointed out hardening is the result of fixing the crystal formation at a given temperature. If the piece is small, the fixing of the crystal formation is quite a simple matter and takes place almost instantaneously. With a large piece, however, the heat is not radiated away from the steel as quickly; therefore the crystals attempt to take on a normal formation, and the fixing operation, that is, quenching, is spread over a period which may be a matter of seconds, resulting in an exterior hardness and soft core. The steel should, therefore, be heated say 50° higher, and on quenching, the core of the steel will be chilled, that is, fixed, before it has had time to change from the hardening state to the soft state. The exterior of the steel will be of slightly coarser grain, but not yet overheated. This important detail is a simple operation to the experienced hardener, and knowledge of it represents the difference between an inexperienced and experienced hardener.

TEMPERING

Tempering.—All tools to be used for cutting, punching or having to withstand heavy stresses should be tempered, either slightly, or almost to the annealed stage. If the tool is slightly tempered very little difference will be observed in the hardness as far as cutting is concerned, but a very great difference will be noticed in the strength of the steel.

Many tools which are quite free from warpage or shrinking after being hardened will move after tempering. The reason for this is the faulty method of tempering, and great care should be observed during this simple operation. Tempering should be done slowly, and the surface of the steel should not be quickly heated, which so often happens.

In tempering the hardener generally raises the temperature of the tool until the surface assumes a predetermined color, such as very light straw to blue. This tint or tarnish, which

is really oxide of iron, is formed on the surface of the steel by the heat of the surface, and there is a distinct lag between the surface color and the actual temperature of the surface of the tool. In fact, a piece of steel can be heated until the surface of the tool will appear a dark yellow, the tool can be kept at the same temperature for 15 minutes, and the steel will then have a surface tint of dark blue, although the temperature has not changed at all.

Noting the temperature of the steel by tints is a rough and ready method and often quite suitable, but where costly tools and intricate shapes are concerned, this rough and ready method is not satisfactory and should not be employed.

It is obvious that if a hot plate or flame be applied to the surface of the tool, the exterior of the tool will quickly take on the temperature of the flame or hot plate, yet the center of the tool will be quite cool. This causes severe surface expansion, which must necessarily add to the internal strains of the steel and often causes the steel to crack.

The best method known is to immerse the tools to be tempered in a cold oil bath and slowly raise the temperature of the oil to a certain definite degree, allowing the tools to remain in the oil for 10 to 60 minutes according to the number of articles being tempered and their sizes. Then let the tools cool down with the oil. This tempering operation is very simple, is extremely inexpensive, and should be adopted for all high grade tools.

CARBON AND ALLOY TOOL STEEL

TEMPER NUMBERS, CORRESPONDING USES AND HEAT-TREATMENTS

TEMPERS

Extra Hard 3X Carbon 1.40

For roll corrugating and chill roll turning tools; for graver tools and all purposes where extreme hardness and fine cutting edge is required.

To Forge—*Heat to bright cherry red* 1425°–1475°F.

To Anneal—*Heat to 1400°F. and slowly cool.*

To Harden—*Heat slowly and uniformly to a cherry red, approximately 1375°–1425°F., quench in oil or water at 65°F.; draw to requirements.*

Hard 3 Carbon 1.25

For lathe, planer and slotter tools generally, small roll thread dies, brass working tools, drawing dies, razors and tools requiring great hardness and fine edge.

To Forge—*Heat to bright cherry red, 1450°–1500°F.*

To Anneal—*Heat to 1400°F. and slowly cool.*

To Harden—*Heat slowly and uniformly to full cherry red, approximately 1385°–1435°F., quench in oil or water at 65°F.; draw to requirements.*

Extra Tough and Hard 33 Carbon 1.10

For small taps, trimming and cutting dies, threading dies, circular cutters, forming and boring tools; also for twist drills, screw dies, roll thread dies, ball races, peen hammers, granite

points, plugs, drawing dies, mandrels, and edge tools generally, razors, and all purposes where a keen tough edge is required.

To Forge—*Heat to bright red, 1500°–1550°F.*

To Anneal—*Heat to 1400°F. and slowly cool.*

To Harden—*Heat slowly and uniformly to a bright cherry red, approximately 1400°–1450°F., quench in oil or water at 65°F.; draw to requirements.*

Star—Extra Tough Carbon 1.00

For milling cutters, taps, trimming dies, saw swages, circular cutters, reamers, mill tools, wood-working tools, form and thread tools, and for all purposes where a very tough and hard edge is required. Welds with care.

To Forge—*Heat to bright red, 1500°–1550°F.*

To Anneal—*Heat to 1400°F. and slowly cool.*

To Harden—*Heat to bright cherry red, approximately 1420°–1470°F.; quench in either oil or water at 65°F.; draw to requirements.*

Tough 4 Carbon 0.90

For punches, large cutting and trimming dies, drop dies, for cold work, mining drills, small shear knives, hand chisels, and all purposes where great toughness with hardness is required. Welds with care.

To Forge—*Heat to bright red, 1500°–1550°F.*

To Anneal—*Heat to 1400°F., and slowly cool.*

To Harden—*Heat slowly and uniformly to a bright cherry red, approximately 1425–1475°F.; quench in oil or water at 65°F.; draw to requirements.*

CHISEL STEEL 44 Carbon 0.80

For large shear knives, punches, chisels, hammers, sledges, cold sets, track chisels, drop forging dies, hammer dies, boiler makers' tools, and all purposes where impact tools are required. Welds with care.

TO FORGE—*Heat to salmon red, 1600°–1650°F.*

TO ANNEAL—*Heat to 1400°F. and slowly cool.*

TO HARDEN—*Heat to a full bright cherry red, approximately 1450°-1525°F.; quench in oil or water at 65°F.; draw to requirements.*

WELDING DIE STEEL 5 Carbon 0.60

For drop forging dies, bolt and rivet headers, hot drop forging dies, ring dies, steel-faced dies, and for all purposes where an extremely tough and hard steel is required. Welds easily.

TO FORGE—*Heat to salmon red about 1600°–1700°F.*

TO ANNEAL—*Heat to 1425°F. and slowly cool.*

TO HARDEN—*Heat to very bright cherry red, approximately 1475°–1550°F.; quench in water or oil; draw to requirements.*

LUDLUM
CARBON TOOL
STEELS

POMPTON SPECIAL
POMPTON EXTRA
POMPTON
ELBA

LUDLUM CARBON TOOL STEELS

High Grade straight carbon tool steels are manufactured by us in the following brands, Pompton Special, Pompton Extra, Pompton and Elba. Each of these grades is supplied in the usual tempers as shown on the preceding pages. All our steels are manufactured in our own specially designed electric crucible furnace, which is a method of manufacturing steel which has proved superior to the old crucible process.

All molten steel when cooling is subjected to local segregation and the occluded gases are liberated into microscopic bubbles. To reduce these occluded gases to a minimum is a very expensive process and calls for high refinements. It is further necessary that this, the highest grade steel, should be very low in metalloid impurities. It is difficult to trace the differences by chemical analysis between our various grades of straight carbon steels. The chemical laboratory, although capable of laying bare the various metalloid impurities, finds it very difficult to trace gases which are to be found in solution in the steel.

After very careful investigation, we have found that by submitting our highest grade straight carbon steel to additional refining in the furnace, we have been able to reduce the occluded gases to the lowest point. This is very expensive and calls for a considerable amount of care on the part of the melter, and, as high grade steel produced in the melting shop can have its value reduced in the rolling mill, very special attention has to be paid to the heating and rolling temperatures.

All our furnaces are equipped with pyrometer control, enabling us to regulate our rolling mill temperatures within a few degrees, great attention being paid to the finishing temperature at the last pass in the rolling mill. The same applies

when the steel is hammered. Our high grade carbon steels are carefully watched and worked during the process of their manufacture and represent the very finest straight carbon steels that have yet been produced.

POMPTON SPECIAL

CARBON TOOL STEEL

Supplied in all tempers, *see pages 68–70.*

POMPTON SPECIAL is the finest quality straight carbon tool steel that can be made and will give great satisfaction, meeting the most severe requirements for cutting and impact tools such as dies, punches, taps, screw dies, chisels, etc. It is particularly free from any tendency to warp or twist on hardening. We strongly recommend this steel where quality is of prime importance.

POMPTON EXTRA

CARBON TOOL STEEL

Supplied in all tempers, *see pages 68–70.*

POMPTON EXTRA is of similar analysis to our finest grade, Pompton Special, but a little less high in refinements. We recommend this steel for lathe and planer tools, dies, finishing tools, shear blades, and all purposes where quality is of first importance. This steel will harden to a good depth and is particularly free from any tendency to warp or twist.

POMPTON

CARBON TOOL STEEL

Supplied in all tempers, *see pages 68–70.*

POMPTON tool steel is excellent for all purposes where straight carbon steels are used. For the price, this steel can not be equalled and, although a little less pure than our better grades, will give excellent results for all purposes where cutting tools or impact tools are used. It will be found to be very reliable and a safe steel to handle.

ELBA

CARBON TOOL STEEL

Supplied in all tempers, see pages 68–70.

ELBA tool steel, although a comparatively low priced steel, will give excellent satisfaction and in some instances is as economical as a higher grade of steel, the chemical analysis being very similar to our high grades but not so super-refined.

A corner of our chipping department where Seminole chisels are used exclusively.

LUDLUM
ALLOY TOOL
STEELS

PEQUOT
ALBANY
SALISH
ARAPAHO
PUEBLO
IROQUOIS SPECIAL
OTSEGO SPECIAL

LUDLUM ALLOY TOOL STEELS

The gap between carbon steel and high speed steel is too large. High speed steel produces a highly efficient cutting tool. Carbon steel is particularly useful for many purposes, but modern day equipment demands something better than a straight carbon steel.

We have endeavored to bridge the gap, and we have developed our Albany, Pequot, Otsego Special and Pueblo brands of steel. The special uses are referred to in the pages of this textbook under their respective headings. Due to the alloys they contain they are somewhat higher in first cost than a straight carbon steel, but the raw material in any finished tool is comparatively small; therefore we recommend the use of alloy steels wherever they can be used in preference to carbon steel which, no matter how efficient it may be, is not as efficient as an alloy steel.

All alloy steels harden to greater depths than straight carbon steels; therefore the effective life of the tool is longer. Steels that harden to greater depths have also a tendency to move less on being hardened than steels that harden to a restricted depth. The grain size of alloy steels is much finer than that of a carbon steel, and grain size has an important bearing on strength.

The temperature to which the alloy steel may be re-heated before softening sets in is somewhat higher in the case of alloy steels than with a straight carbon steel. Under these circumstances longer life when subject to high duty can be expected from an alloy steel.

It is somewhat more difficult to machine an alloy steel than a straight carbon steel but not sufficiently so to materially increase the cost of the manufacture of tools. Alloy steels

are more difficult to anneal, but we do not experience any trouble in this respect, as our experience with such steels has enabled us to work out a satisfactory annealing treatment, allowing us to produce these steels in a very soft state when annealed. Users of our steels can obtain the best annealing treatment from us, so that no trouble need be experienced with machineability.

PEQUOT

ALLOY TOOL STEEL

Supplied in all tempers, *see pages 68–70*.

Pequot brand has greater depth of hardness than straight carbon steel and will last longer in service than our high grade straight carbon tool steel For impact work, where excessive jar is felt on the cutting edge of the tool, Pequot brand is pre-eminently suitable

This analysis has proven very successful for rivet sets, hardening to the necessary depth and retaining an extremely tough core, thus obviating any tendency towards breaking at the fillet

HEAT TREATMENT

To Anneal—*Heat to 1400°F. and slowly cool*

To Harden—*Heat extremely slowly to about 25°F. higher than the temperature given for carbon steel of similar temper number.*

Note.—The full effect of this alloy steel is not brought out unless the steel is very slowly heated and held at the quenching temperature at least 5 to 15 minutes.

Pompton, Pequot and Albany, carbon and alloy steel tools, showing a partial range of successful applications.

ALBANY

ALLOY TOOL STEEL

Supplied in all tempers, *see pages 68–70.*

Chrome and vanadium when used as alloys in tool steel, impart a greater life to cutting edges, and the tools will stand up longer under vibratory stress. ALBANY is the result of very careful investigation in the art of alloying these elements, and we believe that here we have produced an alloyed tool steel that is superior to any other similar type steel.

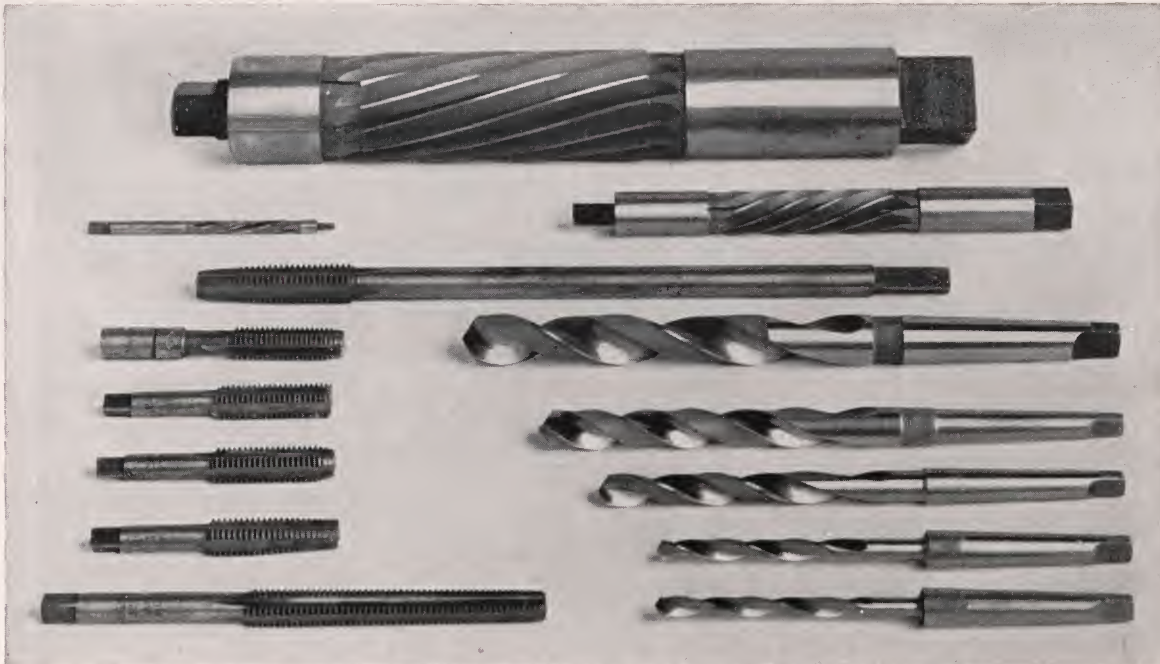
This steel is made under the same high refinement as our Pompton Special and represents an extremely pure steel. We strongly recommend it for expensive taps and screw dies, punches, cutters, and for all purposes where a lasting and very hard cutting edge is desired.

HEAT TREATMENT

TO ANNEAL—*Heat to 1450°F. and slowly cool.*

TO HARDEN—*Heat very slowly to 1500°–1700°F. depending upon the carbon temper and the size. Quench in oil. Draw to requirements.*

NOTE.—The full effect of this alloy tool steel is not brought out unless the steel is very slowly heated and held at the quenching temperature from 5 to 15 minutes, depending on the size of the tool.



Arapaho, Chrome carbon tool steel, showing classes of tools for which it is extremely efficient.

SALISH

CARBON TWIST DRILL STEEL

SALISH has been developed specially for twist drills. It is a very tough and hard steel of the highest grade and extremely homogeneous, free from any tendency to crack in hardening, carries a keen edge, and the corners of the drill will not readily deteriorate in use.

Supplied also in cold drawn bars or coils.

HEAT TREATMENT

TO ANNEAL—*Heat to 1400°F. and slowly cool.*

TO HARDEN—*Heat slowly and uniformly to 1400°–1475°F. Hold at this temperature according to the size, quench in oil or water at 65°F. Draw to requirements.*

ARAPAHO

SPECIAL ALLOY TWIST DRILL STEEL

We have developed a very high grade of alloy steel for twist drills and recommend ARAPAHO for all purposes where a tough, durable, twist drill is required. This steel will carry a very hard, keen edge and is free from any tendency to split. It is safe in hardening, no special instructions being necessary.

HEAT TREATMENT

TO ANNEAL—*Heat to 1425°F. and slowly cool.*

TO HARDEN—*Heat slowly and uniformly to 1450°–1500°F. Maintain at this temperature sufficiently long to allow the steel to become thoroughly saturated Quench in oil or water at 65°F Draw to requirements*

PUEBLO

DROP FORGE DIE BLOCK STEEL

PUEBLO has been developed to meet the requirements for a steel that is more durable than the regular carbon die block steel. The alloys of chromium and nickel seem to meet this requirement in a most efficient manner. Our Pueblo steel is the result of our extensive investigation and practical experience. This steel offers no difficulties in heat-treatment, will withstand deformation, and is extremely resistant to sinking. Die Blocks made of our Pueblo brand will machine very readily and, on being heat-treated, will stand soaking heats without deterioration.

Pueblo has a good penetration on hardening and a very high lateral strength, thereby obviating the troubles experienced from the usual chrome nickel die blocks of breaking in half and splitting at the impression. All Pueblo die blocks are supplied annealed.

HEAT TREATMENT: *Supplied on request.*

IROQUOIS SPECIAL

GOLD LABEL FINISHING STEEL

Iroquois Special is an alloy steel designed for all purposes where a very hard, keen edge is desired. We strongly recommend it for turning chilled rolls and corrugating chilled rolls. It is excellent for gun barrel drills and reamers, engraving tools, and for all purposes where a very hard keen, smooth edge is required, and is quite unexcelled for circular forming tools for automatic machines.

HEAT TREATMENT

To Forge—*Heat slowly and thoroughly to 1550°F.; forge slowly; allow to cool slowly after forging.*

To Anneal—*Heat to 1525°F. and slowly cool.*

To Harden—*Heat slowly and uniformly to 1475°–1600°;F. do not soak; quench in oil or water at 70°F. (not brine); draw to a straw color, or requirements. When using water as a quenching medium the lower range of temperatures must be employed.*

OTSEGO SPECIAL

BULL DIE STEEL FOR HOT RIVET WORK

Our OTSEGO SPECIAL brand for slow compression riveting and hot die work is the result of an unusual combination of alloys and has phenomenal qualities. For bull dies, where a slow compression is used on hot rivets, this steel gives remarkable satisfaction. This steel after heat-treatment will be found soft enough to machine with care. It is so extraordinarily tough and unaffected by the influence of heat from hot rivets that the dies when once made are extremely durable and will last many times longer than those made from other brands of steel manufactured for bull dies.

In the event of the bull die wearing after a long period, the cup can be redressed by being machined; the tool should not under any circumstances be annealed or heat-treated when being redressed in this manner.

HEAT TREATMENT

TO ANNEAL.—*Heat slowly and uniformly to 1450° to 1475°F, very slowly cool in the furnace or in lime, mica, charcoal, or ashes.*

TO HARDEN.—*Heat uniformly to 1525° to 1575°, preferably 1550°F, quench in water until vibration ceases; then transfer to an oil bath and allow to cool down in the oil until cold. The die should be drawn by being heated to 700°-800°F. The die after being hardened and drawn will not be file hard, but will show a Brinell hardness of about 520 to 540.*

LUDLUM
Special Purpose ALLOY
TOOL STEELS

SEMINOLE MEDIUM
SEMINOLE HARD
UTICA
PURPLE CUT
PURPLE HARD
HURON
SENECA

LUDLUM SPECIAL PURPOSE TOOL STEELS

The modern-day expensive machine equipment can not be made use of to its fullest extent if the tools used in conjunction with these machines are not capable of withstanding the high duty work put upon them. This situation was appreciated by the tool steel industry a few years ago, and therefore alloy tool steels have come into greater use and prominence.

In our endeavor to keep stride with machine developments we have produced alloy tool steels which are superior to the more usual grade of alloy tool steels that have been developed within the last few years. Each machine problem or machine tool problem is somewhat distinct unto itself, and no one particular tool steel will do all jobs with maximum efficiency.

In this day of specialized production and manufacture it has become increasingly necessary to produce specialized tool steels. With their use costs can be materially decreased, the life of the tool being increased two and three fold. The cost of a tool is largely the making rather than the tool steel going into it, so that a few extra cents or dollars increased cost in tool steel is only a very small percentage of the total cost of the die or tool, and if the life can be increased 10% to 300%, then the increased cost is well taken care of. Long runs should not be attempted unless the very highest grade high duty tool steel is used for the dies. If this precaution is not exercised tool costs are necessarily high, as the shutting down of the machine to grind or change the dies increases the overhead and adds materially to the cost. To meet the ever-increasing strenuous demand of modern production we have produced these highly specialized alloy tool steels·

SEMINOLE
HURON
SENECA
PURPLE CUT
UTICA

The aforementioned brands of steel are fully explained and their uses given in the text-book on the pages devoted to these particular brands of steel.

UTICA is primarily a tap steel and has been very largely used for this purpose. It has a keen cutting edge and is very tough.

PURPLE CUT is a similar grade of steel but of an entirely different analysis, and one of our large customers who uses this grade of steel in very large quantities advertises it as the most remarkable steel that has been developed within the last twenty years.

HURON is a very high chromium steel of high carbon and will generally do three to four times as much press blanking work as can be obtained with any carbon steel or other type and grade of alloy steel.

SEMINOLE is a chisel steel that can be made sufficiently hard to cut glass yet at the same time can be bent after being hardened, thereby cutting out breakage which is both costly and dangerous.

SENECA is a similar property steel containing higher carbon, generally used for the larger sizes where concussion and cutting is of importance.

The afore-mentioned alloy steels represent a big departure from standard grades of alloy tool steel and are the result of years of research work and experience.

U. S. A. Patent No. 1,468,937, Sept. 25, 1923.

SEMINOLE MEDIUM

HEAVY DUTY CHISEL STEEL

Seminole Medium can best be described as a paradox steel It can be made so hard that it will cut glass, yet it can be bent in this condition. This desirable property has long been sought for, and we, after years of experimentation, have developed such a steel in our brand Seminole.

It is unequalled for chisels, beading tools, rivet sets, and punches. It is easily hardened and does not require the exact heat treatment of a carbon steel, and will outlast a score of chisels made of high grade carbon steel. It is free from any tendency to warp, twist or move in hardening.

Seminole medium is strongly recommended for hand chisels, pneumatic chisels, etc., especially those doing heavy work. Pneumatic tools made of Seminole medium will not crack or break at the fillet.

HEAT TREATMENT

To Anneal—*Heat to 1425°F. and slowly cool, preferably in the furnace.*

To Harden—*Heat to 1550°–1750°F. preferably heating quickly either in a forge fire or a lead pot. Quench in oil. Greater efficiency is obtained from this steel when it is drawn to about a straw color, 400° to 500°F. For all general purposes, oil quenching and no drawing is all that is necessary.*

Pneumatic chisel shanks if left as forged need no further treatment; if annealed and machined, they should be heated up to about 1500°F. and quenched in oil, or to 1500°–1600°F, and cooled in air.

SEMINOLE MEDIUM

Seminole Medium, when heat treated, is one of the strongest steels that modern metallurgy has produced. A close scrutiny of the graph will disclose some very important facts.

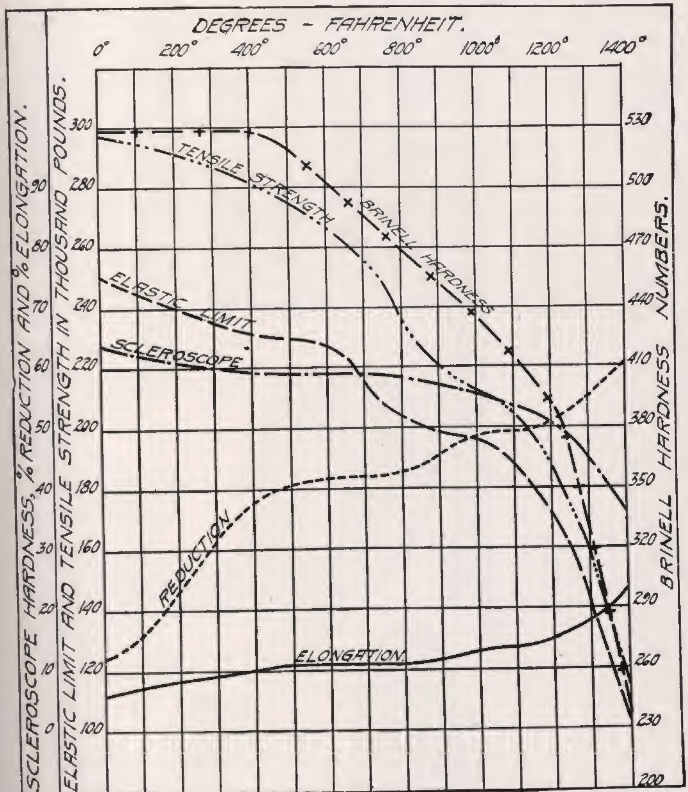
The elastic limit does not fall as quickly as the ultimate strength when a hardened piece is drawn, yet the elongation and reduction of area are high.

The high brinell hardness is maintained in the presence of great ductility.

Seminole Medium is strongly recommended for drive shafts for automobiles and trucks. It is possible to make a lighter shaft and a stronger one with Seminole Medium than has heretofore been possible with the more usual grades of steel, such as chrome nickel, that are usually employed for this purpose. The splines can be cut on the annealed bar and the bar subjected to simple heat treatments which will not cause the bar to warp or twist, while the spline ends can be made file hard, entirely obviating any wear over years of service, yet, at the same time, it is practically impossible to twist off the shaft.

The torque strength of Seminole Medium is considerably higher than that found in other heat-treated steels of about the same ultimate strength and elastic limit.

SEMINOLE MEDIUM—HEAT TREATED PHYSICAL CHARACTERISTICS



The above values are averages obtained from standard test specimens, taken from 1″ Rd sections heat treated as described.

Heat Treatment: Heated for 10 minutes at 1760° F. and quenched in oil. Drawn 30 minutes at temperature indicated.

Drawing temperature	Tensile strength	Elastic limit	Elongation	Reduction	Brinell hardness	Scleroscope hardness
0	296,800	250,000	6.0	12.0	527	64
200	290,800	240,500	8.0	23.0	527	61
400	280,800	231,000	10.0	37.0	525	59
600	267,500	228,500	10.5	41.5	504	59
800	237,000	204,000	10.5	43.0	470	58
1000	212,500	196,000	13.0	49.0	435	55
1200	189,500	174,000	15.0	51.0	392	51
1400	114,000	102,200	23.0	61.0	241	35
Annealed	79,000	48,000	33.0	55.7	153	24

Seminole. — The original unbreakable chisel steel that started a new era in the tool-steel art.

U. S. A. Patent No. 1,468,937, Sept. 25, 1923.

SEMINOLE HARD

HEAVY DUTY CHISEL STEEL

SEMINOLE HARD is a steel very like Seminole Medium; it has similar characteristics. This brand is also primarily a chisel steel, doing particularly well on light or heavy work where a greater hardness is required.

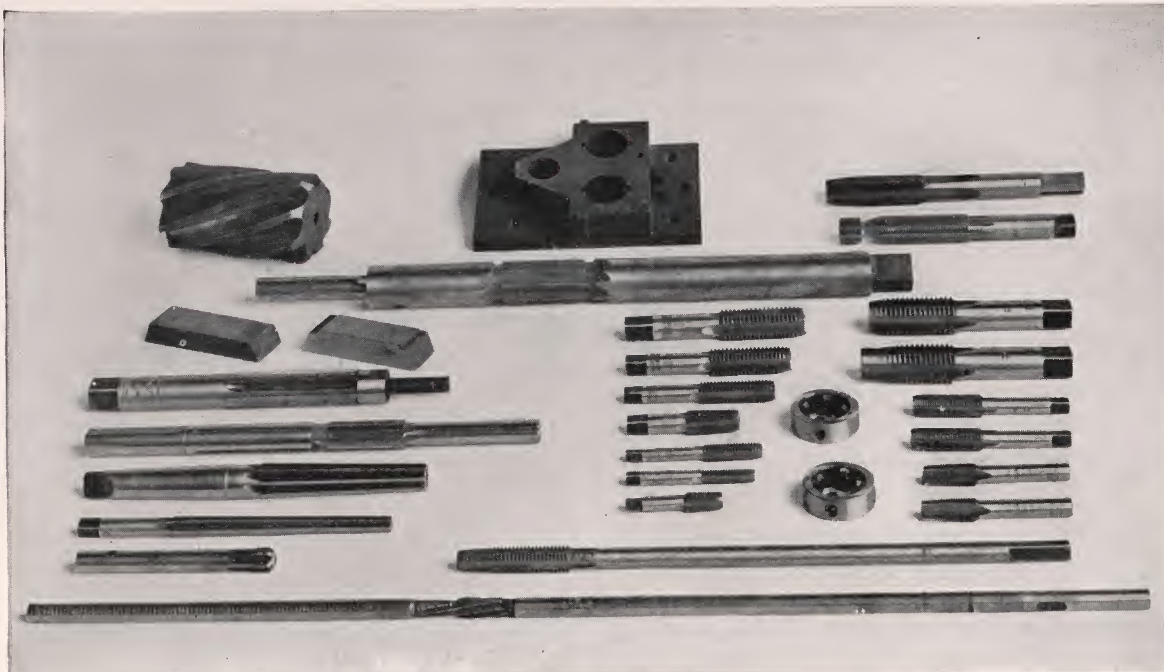
We strongly recommend Seminole Hard for chisels, rivet sets, bull dies, some forms of hot work tools, plate punches and dies, mining drills, hollow drills, and for all purposes, where a hard, non-battering, fatigue-resisting steel is required. Pneumatic chisels made of Seminole Hard are free from any tendency to break or crack under the head.

HEAT TREATMENT

TO ANNEAL—*Heat to 1425°F. and slowly cool preferably in the furnace.*

TO HARDEN—*Heat to 1550°–1750°F. preferably heating quickly either in a forge fire or a lead pot. Quench in oil. To obtain maximum efficiency from this steel, draw after the quenching to at least a straw color, 400° to 500°F. For all general purposes oil quenching and no drawing is all that is necessary.*

Pneumatic chisel shanks if left as forged need no further treatment; if annealed and machined they should be heated up to about 1500°F. and quenched in oil, or heated to 1500°–1600°F. and cooled in air.



Utica alloy steel tools, showing characteristic applications.

UTICA

SPECIAL ALLOY TOOL STEEL

Utica is an intermediary tungsten alloy tool steel that has been specially designed for extremely heavy work. It will carry a tougher and more lasting cutting edge than the usual high grade straight carbon tool steel.

No difficulties will be experienced in heat-treatment; it is very free from any tendency to warp, twist, crack, or check in hardening. It will carry a very hard, keen, durable cutting edge, and is highly recommended for press tools, punches, dies, complicated shapes, taps, reamers, and for all purposes where a hard, keen, wear-resisting edge is desired. This steel is not meant to supplant carbon steel, but should be used where a more durable steel is necessary

HEAT TREATMENT

To Forge—*Heat to 1500°–1550°F.; forge thoroughly, but not below a temperature of 1400°F. After forging, allow to cool in lime, ashes, powdered mica, etc.*

To Anneal—*Heat from 1500°F. to 1525°F.; hold at this temperature for about ten minutes and allow to cool very slowly. It is important to allow the steel to cool very slowly during the first 200 degrees fall in temperature.*

To Harden—*Heat slowly and uniformly to 1500°–1700°F.; do not hold at this temperature longer than is necessary to heat the piece right through. Quench in oil.*

When lead pot hardening is employed, do not hold at the temperature longer than will give the required hardness. Short time heating produces maximum toughness.

The steel should be drawn after being hardened, depending upon the purpose for which the steel is to be used.

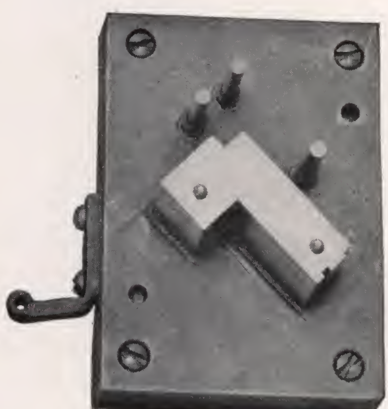
UTICA POLISHED DRILL RODS

Modern high-powered, heavy duty machinery has compelled the adoption of a superior alloy steel having the strength and cutting ability lacking in a straight carbon steel. Our Utica brand from which we are manufacturing polished drill rod meets these requirements completely.

Utica is a tungsten, chromium, vanadium alloy steel combining the essential properties of strength, toughness, and keen edge retention.

Utica Polished Drill Rods in standard sizes can be shipped from stock, and intermediate sizes will be made up to order in lots of fifty pounds or more. Unless otherwise specifically ordered these rods will be furnished in 3-foot lengths.

We can also furnish Utica steel in rough drawn and lime drawn finish.



Utica Punch.

UTICA POLISHED DRILL RODS

Size, Inches	Decimal Equivalent	Pounds per Foot
Price 50¢ per Lb.		
1 1/2	1.500	6.000
1 15/32	1.4687	
1 7/16	1.4375	5.533
1 13/32	1.4062	
1 3/8	1.375	5.062
1 11/32	1.3437	
1 5/16	1.3125	4.600
1 9/32	1.2812	
1 1/4	1.250	4.160
1 7/32	1.2187	3.968
1 3/16	1.1875	3.772
1 5/32	1.1562	3.583
1 1/8	1.125	3.380
1 3/32	1.0937	3.200
1 1/16	1.0625	3.025
1 1/32	1.0312	2.841
1	1.	2.667
31/32	.969	2.508
15/16	.9375	2.341
29/32	.9062	2.176
7/8	.875	2.041
27/32	.8437	1.884
13/16	.8125	1.750
25/32	.7812	1.629
Price 55¢ per Lb.		
3/4	.750	1.500
23/32	.7187	1.388
11/16	.6875	1.265
21/32	.6562	1.150
5/8	.625	1.041
19/32	.5938	.943
9/16	.562	.845
17/32	.531	.756
Price 60¢ per Lb.		
1/2	.500	.667
31/64	.4843	.627
15/32	.4687	.585
29/64	.4531	.544
7/16	.4375	.510
Price 75¢ per Lb.		
27/64	.4218	.471
Z	.413	.455
13/32	.4062	.434
Y	.404	.432
X	.397	.421
25/64	.3906	.407
W	.386	.397
V	.377	.381
3/8	.375	.375
U	.368	.362
23/64	.3593	.343
T	.358	.341
S	.348	.321
11/32	.3437	.316
R	.339	.306
Q	.332	.294

Size, Inches	Decimal Equivalent	Pounds per Foot
Price 75¢ per Lb.		
21/64	.3281	.287
P	.323	.278
O	.316	.272
5/16	.3125	.260
N	.302	.243
19/64	.2968	.236
M	.295	.231
L	.290	.224
9/32	.2812	.211
K	.281	.211
J	.277	.205
I	.272	.198
H	.266	.189
17/64	.2656	.189
G	.261	.182
F	.257	.176
E	.250	.167
1/4	.250	.167
D	.246	.161
C	.242	.155
B	.238	.151
	.236	
15/64	.2343	.146
A	.234	.146
	.228	
1	.227	.137
	.221	
2	.219	.128
7/32	.2187	.127
	.213	
3	.212	.120
	.209	
4	.207	.114
	.2055	
5	.204	.111
13/64	.2031	.109
6	.201	.107
7	.199	.105
8	.197	.103
	.196	
9	.194	.099
	.1935	
10	.191	.096
	.189	
11	.188	.094
3/16	.1875	.093
12	.185	.091
13	.182	.088
14	.180	.086
15	.178	.085
	.177	
Price 83¢ per Lb.		
16	.175	.081
	.173	
17	.172	.079
11/64	.1718	.079
	.1695	
18	.168	.076
	.166	

UTICA POLISHED DRILL RODS—Continued

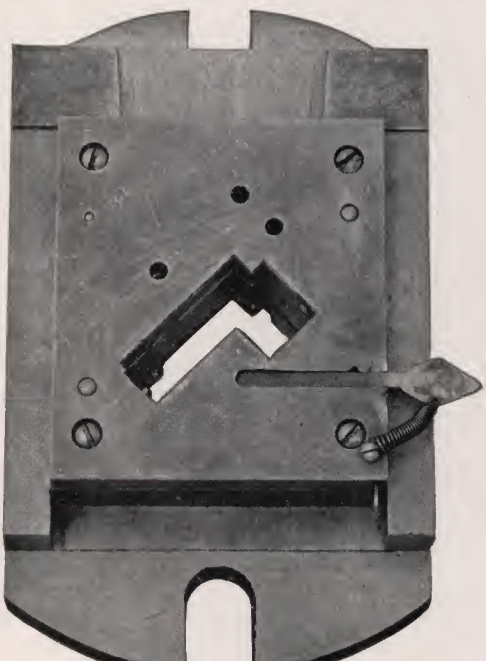
Size, Inches	Decimal Equivalent	Pounds per Foot
PRICE 83¢ PER LB.		
19	.164	.072
20	.161	.069
	.159	
21	.157	.065
5/32	.1562	.064
22	.155	.064
	.154	
23	.153	.062
	.152	
24	.151	.061
	.1495	
25	.148	.058
	.147	
26	.146	.056
	.144	
27	.143	.055
9/64	.1406	.053
28	.139	.052
	.136	
29	.134	.047
	.1285	
30	.127	.044
1/8	.125	.042
PRICE 90¢ PER LB.		
31	.120	.038
	.116	
32	.115	.036
	.113	
33	.112	.033
	.111	
34	.110	.032
7/64	.1093	.032
35	.108	.031
36	.106	.029
	.104	
37	.103	.028
	.1015	
38	.101	.027
PRICE $1.05 PER LB.		
	.0995	
39	.099	.026
	.098	
40	.097	.025
	.096	
41	.095	.024
3/32	.0937	.024
42	.092	.023
	.089	
43	.088	.021
	.086	
44	.085	.019
	.082	
45	.081	.017
46	.079	.016
5/64	.0781	.015

Size, Inches	Decimal Equivalent	Pounds per Foot
PRICE $1.20 PER LB.		
47	.077	.015
	.076	
48	.075	.014
	.073	
49	.072	.0136
	.070	
50	.069	.0127
PRICE $1.45 PER LB.		
	.067	
51	.066	.0113
	.0635	
52	.063	.0105
1/16	.0625	.0105
	.0595	
53	.058	.0087
54	.055	.0078
PRICE $1.80 PER LB.		
	.052	
55	.050	.0064
3/64	.0468	.006
56	.045	.0053
	.0435	
57	.042	.0046
PRICE $2.10 PER LB.		
58	.041	.0044
59	.040	.0042
60	.039	.0040
PRICE $2.40 PER LB.		
61	.038	.0038
62	.037	.0037
PRICE $2.70 PER LB.		
63	.036	.0035
64	.035	.0033
65	.033	.0029
PRICE $3.00 PER LB.		
66	.032	.0027
1/32	.0312	.0025
67	.031	.0025
68	.030	.0024
PRICE $3.30 PER LB.		
69	.029	.0023
	.028	
70	.027	.0020

UTICA POLISHED DRILL RODS — Concluded

Size, Inches	Decimal Equivalent	Pounds per Foot
Price $3.60 per Lb.		
71	.026	.0018
	.025	
72	.024	.0015
73	.023	.0014
Price $3.90 per Lb.		
74	.022	.0013
Price $4.05 per Lb.		
75	.020	.0011
Price $4.20 per Lb.		
76	.018	.0009
Price $4.50 per Lb.		
77	.016	.0007
1/64	.0156	.0006
Price $4.80 per Lb.		
78	.015	.0006
Price $5.10 per Lb.		
79	.014	.0005
Price $5.40 per Lb.		
80	.013	.0004

Discount upon application.



Utica Die.

Purple Cut, alloy tool steel, especially suited for applications requiring a lasting, keen, hard cutting edge.

U. S. A. Patent No. 1496978 — June 10, 1924
U. S. A. Patent No. 1496979 — June 10, 1924
U. S. A. Patent No. 1496980 — June 10, 1924

PURPLE CUT

NON-SHRINKING TAP & THREADING DIE STEEL

PURPLE CUT is a new and remarkable tool steel, probably the most interesting tool steel development in the last twenty years. It is an alloy steel containing silicon, molybdenum, chromium, and high carbon, which will maintain a keen cutting edge when operating at a purple heat. The cutting edge becomes harder by wear rather than softer, as is usual with most tool steels. Purple Cut can be made file hard when quenched in oil, and will not deform, warp or crack.

Purple Cut can be hardened over an extremely wide range of temperature, which adapts it to a large number of uses. It is the only known high carbon tool steel that is tremendously tough when file hard and hardened right through.

This steel is especially recommended for taps, cutters, reamers, threading tools, twist drills, gauges, punches, and is particularly efficient for machining brass, bronze and aluminum.

HEAT TREATMENT

TO FORGE—*Heat uniformly to 1700°–1900°F. depending upon the size of the piece and the amount of work to be done; finish forging at about 1500°F. Cool preferably in lime or ashes. Do not harden from forging heat.*

TO ANNEAL—*Heat to 1500°–1525°F. and cool very slowly, preferably in the furnace.*

TO HARDEN—*Heat uniformly to 1525°–1825°F.; quench in oil. Draw to requirements, for cutting tools about 500°F.*

U. S. A. Patent No. 1496979 — June 10, 1924
U. S. A. Patent No. 1496980 — June 10, 1924

PURPLE HARD

CARBURIZING STEEL

Purple Hard is a remarkable carburizing steel that takes up carbon faster than any known carburizing steel, can be carburized at ordinary carburizing temperatures, 1650°–1750°F., or can be carburized at higher temperatures if desired. The highest temperatures used for carburizing have no detrimental effect upon the core; the steel after being carburized can be quenched out in oil from the carburizing heat, giving a great depth of hardness and complete absence of any possibility of trouble from spalling (exfoliation). The percentage of carbon from the high carbon of the case to the medium carbon of the core is so well graded that from a fracture it is almost impossible to discern where the high carbon leaves off and the low carbon begins.

The surface is quite file hard and extremely tough. It is difficult to shatter it with a hammer. The core is extremely strong and resists deformation to a very marked degree; therefore there is practically no chance for the case to crack due to deformation of the core.

It is the only carburizing steel that has been developed to this day that will give good results as an edge cutting tool such as a tap, reamer, or threading tool. It will withstand 650°F. drawing temperature without materially softening the case.

The principal and outstanding points of efficiency are:

1. It has high speed of case carburizing.
2. It does not require re-heating to refine the core.
3. It can be oil hardened and made file hard.

4. It has entire absence of any line of demarkation between carburized structure and non-carburized.

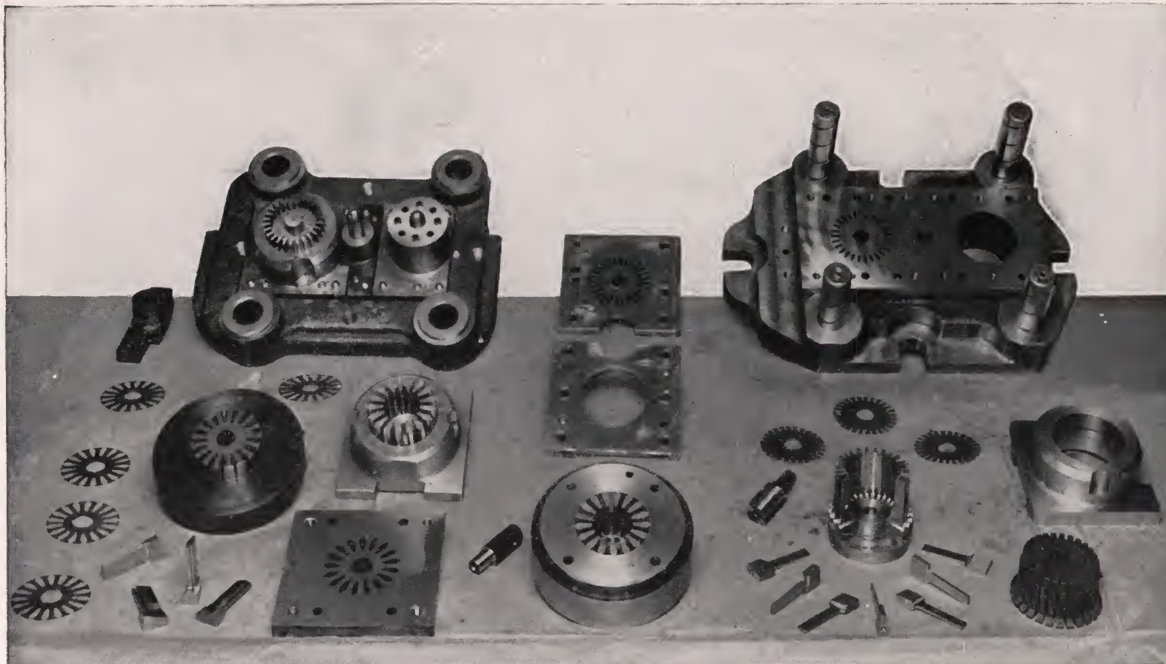
5. It has a very strong core, and is not easily deformed.

6. It is easy to machine and forge.

7. It will not deform, crack, warp or check when quenched in oil.

8. It takes on a glazed hard surface when subject to wear adding to the already great hardness of the hardened exterior.

9. It is inexpensive to handle and has low working costs.



Huron is a high carbon, chromium, tool steel, unequalled as a press tool, especially for blanking armature laminations.

HURON

SPECIAL ALLOY PUNCH AND DIE STEEL

Our Huron brand is the result of our extensive experiments in the development of an alloy steel which will give superior results for blanking silicon transformer sheets and armature discs. This brand of steel in practice has lasted two or three times longer than any other steel developed for this purpose and we recommend Huron for punches and dies, for thin sheets and heavy material, also for drawing, threading, forming, thread rolling and mint dies, taps, reamers, and plug and ring gauges.

Huron is an oil hardening steel and is particularly free from any tendency to warp or twist in hardening. This steel will harden to a great depth, and the life of the die after each grinding is consistently uniform.

HEAT TREATMENT

To Forge—*Heat slowly and uniformly to approximately 2000°F. Do not work under 1600°F. Allow to cool slowly after forging.*

To Anneal—*Heat slowly and uniformly to 1550°–1650° F. Hold at this temperature according to the size of the tool and then cool extremely slowly.*

To Harden—*Heat slowly and uniformly to 1700°–1750°F. hold at this temperature for 10 to 30 minutes, making sure that the piece is thoroughly heated through at the temperature used; Quench in oil and draw to requirements.*

SENECA

ALLOY PUNCH AND DIE STEEL

SENECA is a tungsten alloy steel and gives very good results for punches, dies, and all purposes where a very tough, durable edge is required. This steel has a very close, dense structure and will outlast similar steels for this class of work. It hardens to a great depth, carries a very hard edge, and has great anti-fatigue properties

HEAT TREATMENT

TO ANNEAL—*Heat to 1425°–1475°F. and cool slowly.*

TO HARDEN—*Preheat if desired to 1350°F., then heat slowly and uniformly to 1650°–1750°F. Hold at this temperature for a period not longer than necessary to heat the tool right through. Quench in oil; draw to requirements.*

LUDLUM
STABLE SURFACE
IRON & STEEL

NON-CORROSIVE IRON & STEEL

NEVA-STAIN STEEL
DELHI TOUGH RUSTLESS IRON
DELHI HARD RUSTLESS STEEL
SILCROME HEAT RESISTING STEEL

NON-CORROSIVE STEELS

The first attempts to produce a non-corrosive iron compound probably go back to the dim and distant past. Some very excellent monuments have been handed down through the ages demonstrating the incorrodible nature of some types of irons and iron alloys.

There are a number of elements which have been known for many years to the metallurgical world to have the property of increasing iron's resistance to oxidation. One of the early nonstaining steels using chromium and iron was produced for cutlery and other stain resisting purposes in the year 1872 in Great Britain. Since that time extensive researches have been made by various investigators all over the world. The principal alloys used have been chromium, nickel and copper with quite a number of combinations using molybdenum which seems to have an added property of resisting the action of acids when used in conjunction with chromium.

All of these alloy combinations are difficult to work, and this, perhaps, is one of the principal reasons for their restricted use.

We have carried on extensive investigations ourselves with the result that we have produced an alloy of iron, chromium and silicon which has resulted in a more non-corrosive alloy than any previously recorded. The chromium silicon steels can be made within fairly wide limits, variable according to the type of oxidation they have to withstand. This new patented alloy is very easy to work and does not have any of the old difficulties. It can be forged and rolled with great ease, hardened without difficulty, and annealed so that it will machine easily. It is capable of taking a very high mirror finish and is highly resistant to the action of nitric acid, acetic acid, fruit acids, and atmospheric and salt water corrosion.

This remarkable alloy combination is also extremely durable at high temperatures, has excellent physical properties when red hot and can be maintained at a yellow heat temperature for many months without the surface scaling and with practically no physical change.

No alloys of other series have yet been developed which have so many remarkable non-related properties.

Delhi Tough Rustless Iron. Note brilliancy of polish.

U. S. A. Patent No. 1322511—Nov. 25, 1919
U. S. A. Patent No. 1456088—May 22, 1923

NEVA-STAIN

SPECIAL NON-CORROSIVE STEEL

Neva-Stain is a high carbon, alloy steel containing high silicon and chromium. The silicon content enables the alloy steel to carry a high carbon obviating the generally accepted forging difficulty that accompanies high carbon steels. It cuts down the tendency towards air hardening and enables the chromium to dissolve into the iron so completely that a lower amount of chromium can be used than would be necessary to produce a rustless and stain-resisting steel with the high carbon employed. Stain resisting steels that are to be used for cutlery purposes and for knives generally have been found wanting because of the inability to impart to these steels a keen and lasting edge. It is very well known indeed that to impart a keen and lasting edge high carbon is necessary, and this is equally true when high alloys are employed. Heretofore it has not been possible to produce a high carbon alloy steel which was rustless and stain-resisting. Neva-Stain steel, due to the high silicon employed, will carry sufficiently high carbon to give it the necessary keen and lasting cutting edge.

Neva-Stain, the patented alloy steel, is very non-corroding and can be exposed to the atmosphere for a very long time without any signs of atmospheric corrosion. It is particularly adapted for exposed surfaces which have to withstand the combined action of salt water and the atmosphere. It can be hardened by heating and quenching and made file hard, and can then be drawn to requirements. It is particularly free from any tendency towards warping, cracking, checking, etc.

Neva-Stain non-corrosive steel can be very readily forged. No difficulties are experienced as to seaming or cracking.

Neva-Stain is a high carbon, silicon, chromium rustless steel; will carry a keen cutting edge that does not readily deform; will not rust nor stain in ordinary service.

Neva-Stain steel, if polished or cleaned, will retain its finish indefinitely. It is not necessary to grease or oil or protect the surface in any way.

Neva-Stain will carry a keen cutting edge, has an excellent spring temper, will not readily take a permanent set, and is very similar in these characteristics to high grade, high carbon cutlery steel.

HEAT TREATMENT: *Supplied on request.*

PARTIAL LIST OF USES

CUTLERY

Knife Blades from Bar Stock.
Knife Blades from Sheet Stock.
Pocket Knife Blades.
Razors.
Razor Blades.

GENERAL USES

All forms of scissors.
Cutlery in all forms.
Cutter blades and small or large mincing machines.
Dental tools.
Fruit cutting machine knives and parts.
Knives for bacon slicing machines.
Lemon cutting machine knives.
Marmalade and preserve machine cutting knives.
Mowing machine blades.
Skate blades.
Surgical instruments.

U. S. A. Patent No. 1322511—Nov. 25, 1919

DELHI TOUGH

RUSTLESS IRON

Delhi Tough is a very low carbon (averaging .07 carbon), high silicon, chromium, alloy iron. It cannot be hardened by heat treatment as there is not sufficient carbon present to enable this alloy iron to be hardened; therefore its application is all in the soft, or annealed, condition. It is more rust-resisting than any alloy iron yet produced. It will withstand completely the action of atmospheric and salt corrosion, mine waters, etc. It is completely resistant to the action of nitric acid, concentrated or diluted, and to most alkalies, organic acids and corrosive liquids. It can be forged with ease, and when annealed can be almost as readily machined as screw machine stock.

Delhi Tough has high physical properties; although almost as ductile as iron, it has about 50% higher ultimate strength and elastic limit. It has a modulus of elasticity of approximately 27,000,000. A bolt made out of Delhi Tough will withstand two to three times the load that is generally considered safe with bronze, and is equally as non-corrosive as bronze, if not more so, except in mineral acids such as sulphuric and hydrochloric. It is, however, very resistant to the action of nitric acid. It is particularly adapted for all structural purposes where the iron is required to be in the soft state and where rustless and non-corrodible material is necessary. Weight for weight, it requires less Delhi Tough to do the same work as iron or mild steel, and in a large number of instances it is less costly to employ Delhi Tough than structural steels. It has a very excellent wearing surface, having the property of wearing hard by glazing in service, yet the surface hardness brought about by wear (glaze) is of

such infinitesimal depth that it has no effect upon the physical properties of the metal.

Delhi Tough should be acid pickled or machined, and in common with all metals, the higher the polish, the brighter the surface will remain. If a forged bar of Delhi Tough is exposed to atmospheric or salt water corrosion, the scale on the surface of the bar from hot forging will decompose and produce a very rusty surface. The rust, however, will not go through or into the bar.

Delhi Tough is non-corrodible and non-oxidizable when heated to temperatures not in excess of 1800°F., and it can be held at this temperature for months without any perceptible scale forming on the surface other than a slight bronzing effect. Delhi Tough has very good physical properties when heated and will withstand the action of corrosive gases at high temperatures. It can be readily drawn or rolled into any desired shape; and it can be cold drawn into wire of extremely small dimensions. In the cast form it is excellent for various non-corroding purposes, valve fittings for steam and water, and for all applications where high heats are to be encountered.

Delhi Tough cannot be cut by the oxyacetylene torch, as the impinging oxygen has the effect of blowing the heated surface cold again without material oxidization. It can, however, be readily oxyacetylene welded, and the filler rod, if used, should be of Delhi Tough.

HEAT TREATMENT

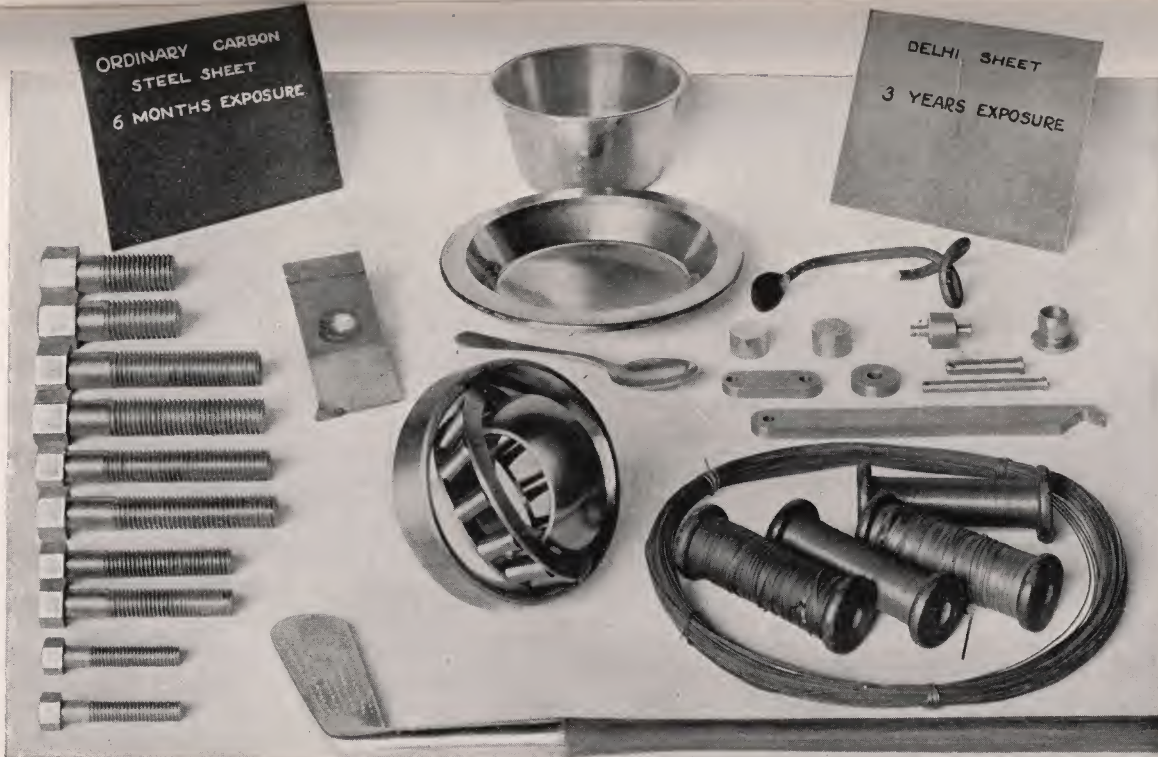
TO FORGE—*Heat to 2000°F. and forge in the usual way. It can be forged down to a black heat. It will forge almost as well black hot as at a high temperature. This iron will not harden. Heating and quenching will not make this iron hard. Such treatment has a softening effect by taking out what strains there may be put into the material by mechanical working.*

To Soften, or Anneal—*Heat to 1300°–1350°F. and allow to cool. Air cooling or quenching from the softening, or annealing, temperature does not produce hardness, but has a softening effect.*

Note.—The maximum physical and non-corroding properties of Delhi Tough are brought out when the material is fully softened, or annealed.

A partial list of uses is to be found on pages 138-139.

Delhi Tough Rustless Iron Bowl.



Delhi Tough Rustless Iron will withstand the atmosphere indefinitely without corrosion.

DELHI TOUGH RUSTLESS IRON

CORROSION RESISTANCE

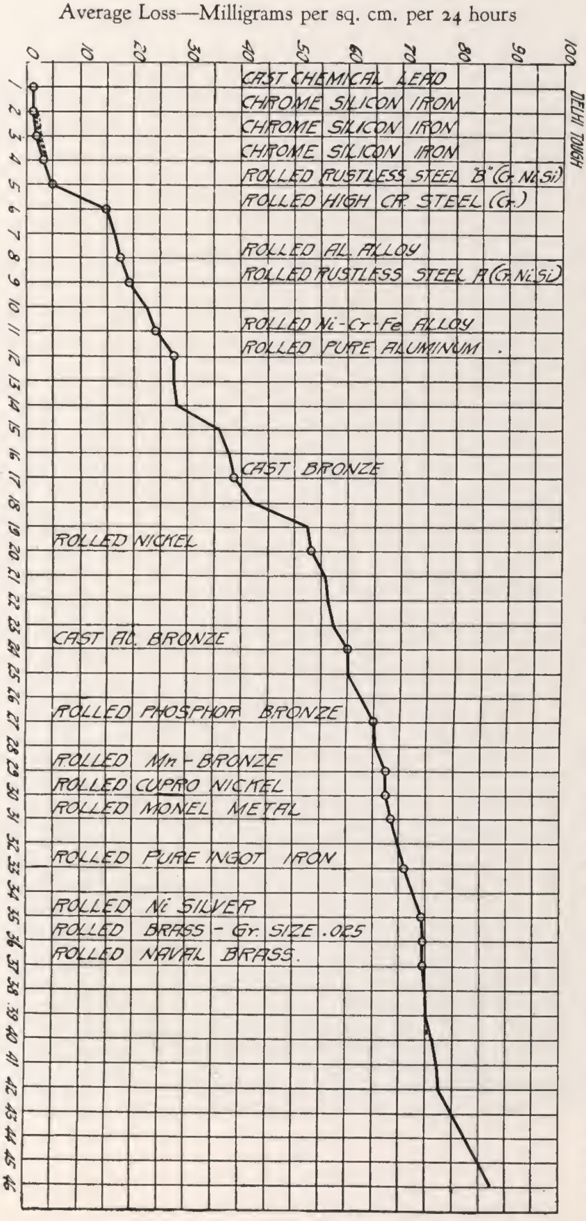
The information given in the diagram on the preceding page was compiled from statistics given in Bulletin No. 6, "Coal Mining Investigations", Carnegie Institute of Technology, 1923. The silicon, chromium, iron alloys (numbers 2, 3 and 4 on the chart), of which Delhi Tough Rustless Iron is a representative type, are seen to be greatly superior to all metals tested except lead, which has equal corrosion resistance, but which lacks the other necessary properties. All of the metals and alloys were tested under identical conditions in an accelerated electrolytic test in which the electrolyte was acid mine water from the Edna No. 2 Mine.

LIST OF METALS TESTED

WITH NUMBERS AS SHOWN IN DIAGRAM

1 Cast Chemical Lead.
2 Rolled Chrome–Silicon Iron.
3 Cast Chrome–Silicon Iron.
4 Rolled Chrome–Silicon Iron.
5 Rolled Rustless Steel "B"
6 Rolled high chromium steel.
7 Cast aluminum–silicon alloy.
8 Rolled aluminum alloy.
9 Rolled rustless steel "A".
10 Cast aluminum–manganese alloy.
11 Rolled nickel-chromium-iron alloy.
12 Rolled pure aluminum.
13 Rolled nichrome.
14 Rolled aluminum manganese alloy.
15 Cast leaded bronze.
16 Cast leaded zinc bronze
17 Cast bronze.
18 Cast leaded bronze.
19 Cast copper-lead alloy.
20 Rolled nickel.
21 Cast tin-lead-nickel silver.
22 Cast leaded cupro-nickel.
23 Cast silicon-nickel silver.
24 Cast aluminum bronze.
25 Rolled iron-aluminum bronze.
26 Cast iron-manganese cupro-nickel.
27 Rolled phosphor bronze.
28 Cast chromium iron cupro-nickel
29 Rolled manganese bronze.
30 Rolled cupro-nickel.
31 Rolled monel metal.
32 Rolled cupro-nickel (coin metal)
33 Rolled pure ingot iron.
34 Rolled copper-manganese-iron alloy.
35 Rolled nickel-silver.
36 Rolled brass Gr. size, 0.025 mm
37 Rolled naval brass.
38 Rolled bronze.
39 Rolled brass Gr. size, 0.035 mm.
40 Rolled zinc phosphor bronze.
41 Cast tin-lead-nickel silver.
42 Rolled low brass.
43 Rolled brass Gr. size 0.075 mm.
44 Rolled iron-nickel silver.
45 Rolled high brass.
46 Rolled nickel silver.

RESULTS OF ACCELERATED CORROSION TEST IN ACID MINE WATER



DELHI TOUGH RUSTLESS IRON

Physical Properties

As Compared with Non-Ferrous Alloys

MATERIAL	Ultimate Strength lbs. per sq. in.	Elastic Limit lbs. per sq. in.	Elongation % in 2 in.	Modulus of Elasticity
Delhi Tough..........	80–85,000	45–50,000	35–40	27,000,000
Aluminum, as cast.....	12,000	....	Practically nil	10,000,000
Aluminum, rolled and annealed.........	12,500	3–5,000	25–35	10,000,000
Aluminum, rolled hard.	20–22,000	14–18,000	1–3	10,000,000
Brass................	58,500	34,500	37	11,500,000
Bronze, Manganese....	72,000	32,000	37	15,400,000
Bronze, Phosphor.....	70,500	42,000	25	11,500,000
Bronze, Titanium.....	80,000	22,000	29½	12,000,000
Nickel Silver.........	77,500	35,000	26	16,200,000
Monel Metal.........	75,000	30,000	35	25,000,000
Muntz Metal.........	63,000	20,000	44	12,500,000
Muntz Metal, with tin.	73,000	35,000	28	14,000,000

Note—Most non-ferrous materials do not stretch proportionately to the stress applied, but at each succeeding application of the same unit stress, stretch a little more than for the same preceding unit stress. Such materials consequently really have no true elastic limit or modulus of elasticity. They exhibit creeping, or plastic flow; that is, they may be stressed to a certain point and keep on stretching without any greater application of load. For example, a bolt drawn up tightly by the nut can become loose through plastic flow.

Delhi Tough does not exhibit plastic flow and will not continue to stretch under a given constant load below its elastic limit. The high modulus of elasticity is an index of Delhi Tough's adaptability to the manufacture of bolts—which once tightened up will remain tight.

Roughly, a 1″ bolt of Delhi Tough Rustless Iron will withstand the same load as a 1½″ bolt of bronze without the objectionable slackening always present in Bronze bolts.

Delhi Tough bent and hammered cold without fracture.

A portion of our billet grinding-department, well lighted, and freed from dust by a powerful ventilating system.

U. S. A. Patent No. 1322511—Nov. 25, 1919

DELHI HARD

RUSTLESS STEEL

DELHI HARD rustless steel is very similar to our Neva-Stain steel, see page 125. The only difference between these two steels is the chromium content. Delhi Hard contains more chromium, about the same silicon, and a carbon content of over 1%. It is completely stain-resisting in the soft, or annealed, and hardened conditions; it is rustless only when hardened. THE PROPERTIES OF STAIN RESISTANCE AND RUST RESISTANCE ARE NOT THE SAME AND CALL FOR DIFFERENT QUALITIES IN AN ALLOY STEEL. It can, however, be made practically file hard, but a cutting edge cannot be made so rigid with Delhi Hard as it can be with Neva-Stain. Delhi Hard is better suited for machine parts.

Delhi Hard is particularly suitable for balls for valves and ball and roller bearings and super-heated steam parts, where maximum corrosion resistance is required with good hardness and wear-resisting properties. The high silicon content enables the high carbon, high chromium Delhi Hard to be readily forged without any tendency towards cracking or checking. When fully annealed, Delhi Hard can be readily machined. On hardening it will not warp or crack. It has very excellent physical properties in the annealed, hardened and drawn condition, having high ultimate strength and elastic limit with good ductility and elongation, depending upon the condition in which it is left after heat treatment.

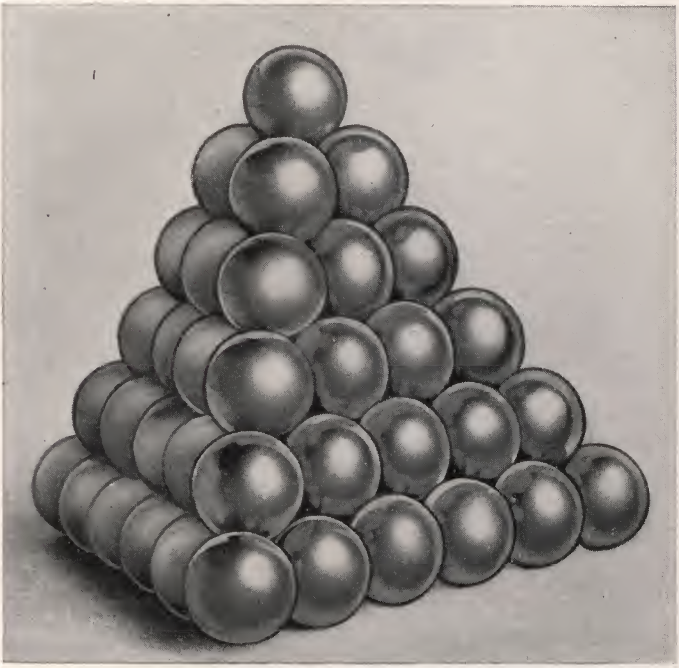
HEAT TREATMENT

TO FORGE—*Heat to 2000°F. and not below 1300°F. The lower the temperature, the stiffer the steel will be to forge, but a low forging temperature does not set up cracks.*

To Soften, or Anneal—*Heat to 1650°–1750°F., holding at this temperature for 1 hour if in an open furnace, or, if packed, for 4 or 5 hours, depending upon the size of the charge.*

To Harden—*High temperatures are necessary. Heat to 1850°–1950°F.; quench in oil. No additional hardness is imparted by quenching in water. Draw to requirements.*

A partial list of uses will be found on pages 138-139.



Delhi Hard acid resisting balls for ball valves in the oil industry.

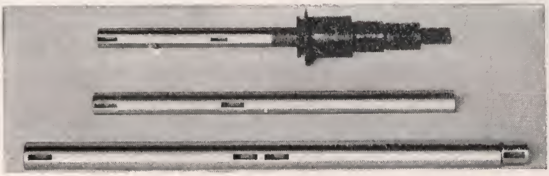
DELHI RUSTLESS IRON AND STEEL

PARTIAL LIST OF USES

Adding machine parts.
Agricultural machinery parts.
Air pump rods.
Air containers.
Air compressors.
All forms of chains.
All forms of shower bath fittings and water fittings generally.
Altimeter vacuum chamber of the averoid.
Auto parts and fittings.
Automobile horns and exposed parts
Automobile engine parts, not valves.
Bolts and nuts.
Bottling machinery.
Buckets.
Candy machine kettles.
Camera parts.
Caps for bobbins on bobbin machines.
Cartridge dummies for the precipitation of copper.
Chemical containers, nitric acid and inorganic acids, alkalies, etc.
Cigarette cases.
Condensor tubes.
Confectionery machinery parts.
Containers for liquid air.
Cotters for air pump rods.
Cotters for steam valves.
Cotton mill work.
Crank shafts for internal combustion engines.
Cream separator parts.
Cuff links.
Culinary utensils.
Cutters.
Cylindrical vessels.
Dairy apparatus.
Dairy machinery.
Diaphragms for phonographs.
Dies for aluminum and brass casting.
Donkey engines, etc.
Dressmakers forms.
Driving machinery parts.
Dummy cartridges.
Dynamo parts.
Dye machinery parts.
Engine bolts.
Electrical instrument parts.
Engine parts.
Engraving plates which do not have to be hard.
Evaporating pans.
Eyelets.
Filter plates.
Fishing tackle generally.
Fishing reel and rod parts.
Fitments on military accoutrements.
Foundry tools.
Forceps.
Gas meter parts.
Gear parts for marine work.
Gears for marine work.
Glass making parts.
Golf clubs.
Gun and rifle barrels.
Gun parts.
Gun barrels.
Hanging rails in butcher shops.
Hardware generally.
Head lights, particularly the reflector.
Horse bit parts.
Hot water tanks.
Hub caps for automobiles.
Hydraulic cap screws.
Hydraulic fittings.
Hydraulic rams.
Ice machinery.
Ice moulds.
Kitchen utensils.
Lace machinery parts.
Lamp parts.
Laundry machines.
Lemon cutting machinery.
Locks.
Machinery parts subjected to the action of water and waste compounds.
Medical apparatus.
Metal patterns.
Military scabbard parts.
Mirrors
Monuments.

DELHI RUSTLESS IRON AND STEEL
Continued

Motor parts which have to be rustless.
Musical instruments.
Nails for boats.
Nuts and bolts for steam engines and turbines.
Ornamental jewelry.
Ornamental parts for ships.
Outdoor fittings.
Paper and pulp machinery parts.
Paper machinery parts.
Periscope mirrors.
Periscope tubes.
Piano player parts.
Pots, pans, etc.
Press rod, rams, etc
Printing block rollers
Propellor shafts.
Propellors.
Pump parts.
Pump valves.
Rammers.
Rifle barrels.
Rods.
Ring and shackles.
Rings for dye beds.
Rings for ring spinning machines.
Sandford generator parts.
Saddlery and hardware.
Screws for mountings, on guns.
Sewing machine parts.
Shafting.
Ship parts and fittings aboard ship such as portholes, covers for port holes, ship rails, handles.
Shoe horns.
Shoe machinery parts.
Slicing machine parts, not the knife.
Soap ploddders.
Soap making machinery generally and tools.
Some parts of mining machinery.
Spinners and spinning machinery.
Spoons.
Spraying machines.
Steam and water pipes.
Steam flat for felt carpet manufacturers
Steam trap parts.
Steel brads for boats in place of copper brads.
Submarine parts.
Studs.
Surgical plates for splints.
Talking machine motor parts.
Tanks for boats.
Telephone parts.
The hulls for racing yachts.
Torpedo nets.
Turbine blades.
Typewriter parts.
Valve parts for air compressors.
Vulcanizing moulds.
Watch cases.
Water meter parts.
Water tubes.
Water turbines.
Water wheels.
Weighing machine parts, particularly scale beams.
Wire
Wire for armoured submarine cables.
Wire netting.
Yacht fittings.



Silcrome. High Chromium.

Silcrome Unburnable Engine Valve Steel, as compared with the best previous material, a high chromium steel. Silcrome does not progressively scale.

U. S. A. Patent No. 1322511—Nov. 25, 1919
U. S. A. Patent No. 1456088—May 22, 1923
U. S. A. Patent No. 1495504—May 27, 1924

SILCROME

HEAT RESISTING STEEL

SILCROME is a medium carbon, high silicon, chromium steel containing more silicon by volume than chromium, specially designed for automobile valves and internal combustion engine valves. It will withstand high temperatures without burning; it can be heated to 1700°F. for months without any appreciable scale forming on the surface. The scale that is present after prolonged heating is in the form of a bronze colored film which is closely adherent and cannot be detached except by grinding, machining, etc.

As an automobile valve, Silcrome will not burn, pit or warp. Silcrome exhaust valves after many months of service in a cylinder in which heavy carbonizing is taking place will be free from carbon. Valve stems will not stretch under the head with normal spring tension.

Silcrome has no air-hardening properties—a matter of prime importance in automobile valve applications. It can be readily forged without any tendency towards cracking or seaming. When softened, or annealed, it will machine well.

PARTIAL LIST OF USES

Automobile valves—exhaust and intake.
Carburizing boxes.
Fire bars.
Furnace hearths.
Furnace linings.
Hot gas turbine blades.
Muffles.
Retorts.
Tongs.
Valves for all internal combustion engines.
Valves for Diesel engines.
Various internal combustion and autombile engine parts that are subjected to wear and deterioration by gases of combustion.

Ludlum annealing is entirely in pipes sealed against the atmosphere.

LUDLUM
BALL-BEARING
STEEL

TETON

BALL-BEARING STEEL

Ball Bearing Steels can be placed in two classes: Case or carbonizing steels and straight hardening steels.

The manufacture of ball and roller bearings calls for high duty material. The balls must be made of a steel which is entirely homogeneous throughout its mass and capable of withstanding enormous pressures for very short periods without any tendency towards disintegration at the point of contact. It is also of prime importance that the steel shall quickly recover from temporary fatigue. The ball under load has a constant tendency to deflect at the ever advancing point of contact, and this highly stressed surface must be able to recover in the time allowed between the arrival of the stressed particle from its contact with the inner race to the outer race, therefore having a period equal to half its diameter for this recovery, and when the ballbearing is subjected to very high speeds and heavy loads, the time allowed for recovery is obviously of very short duration. These conditions have resulted in the almost universal use of straight hardening steel for balls.

Ball races are subjected to even more high duty than the balls as their stressed area is virtually a line contact around the periphery of the race, and the time allowed for this highly stressed line to recover is even shorter than that of the ball. Furthermore, the excessive loads to which the ball is subjected are spread evenly over the surface of the ball, due to slight axial misalignment, whereas the race has but one line of highly stressed contact.

The stressed surface of a roller bearing is practically the same as that in a ballbearing, but the bearing pressure per unit of surface is not quite so high; nevertheless the same high duty material is essential. We have developed a special analysis of chrome steels to take care of these enormous stresses.

TETON

SPECIAL BALL BEARING STEEL

This high grade ball bearing steel is very low in impurities and capable of being hardened right through, the micro-structure throughout the mass being extremely consistent. Teton is quite free from any of the objectionable hard microscopic points which are so present in chrome steels due to local segregation of chrome-carbide; therefore this steel has no tendency to spall (shell off). We recommend this brand for balls and rollers. We can supply this steel in cold drawn bars and coils, specially heat-treated—annealed.

HEAT TREATMENT

To Anneal—*Heat to 1425°F. and cool very slowly.*

To Harden—*Heat slowly and uniformly to 1475–1625°F., holding at this temperature sufficiently long to insure the complete saturation of the steel. Quench in oil. Draw to requirements.*

LUDLUM
PERMANENT MAGNET
STEEL

TUNGSTEN MAGNET STEEL
ATSINA
CHROME MAGNET STEEL
YUMA

PERMANENT MAGNET STEEL

The Ludlum Steel Company was one of the first steel manufacturers to make chrome magnet steel and has been a large producer of this grade of magnet steel since that time. We manufacture two grades of magnet steel, tungsten and chrome magnet

In developing a permanent magnet steel, there are a number of points to consider besides that of just what will make the best permanent magnet. The steel must be capable of being melted without a tendency for any of the constituents to separate out on freezing; it must be capable of being readily rolled, so that a minimum amount of heating is necessary; the work to be done on the billet in rolling it to the finished size must be performed so that the finishing temperature is of a predetermined value; and the steel may not be so air-hardened that it is impossible to work it without annealing. Annealing chromium or tungsten magnet steel reduces their magnetic values unless very great care is taken, and at the most only indifferent annealing can be done if the highest magnetic qualities are to be obtained.

The following points are also of prime importance:

1. The steel must have a large hysteresis coefficient to give it the necessary retentivity.
2. It must be capable of being made extremely hard.
3. The micro-structure must be very stable and not affected by slight temperature changes.
4. The magnet steel, when hardened and magnetized must not be subject to undue secular changes.
5. The steel must be absolutely homogeneous.

The principal magnetic properties in which the user of magnet steel is interested are: first, the amount of magnetism

that goes through the steel, which is usually indicated by maximum PERMEABILITY at a given magnetizing force. This given magnetizing force is located well beyond the so-called knee of the curve, that is to say in the region where any further increase of field strength or magnetizing force does not give any real increase in the magnetic induction.

After having ascertained the maximum amount of magnetism that will go through a bar of steel at a given magnetizing force, the next point of interest is what is usually termed the RESIDUAL INDUCTION, that is, how many of these lines will remain resident, or permanent, in the magnet steel after the magnetizing force is reduced to zero.

Another point of interest is the COERCIVE FORCE, which indicates what strength of field must be induced to remove entirely all the lines of induction that are residual in the magnet steel. The COERCIVE FORCE is generally taken as an index of how permanent the residual magnetism will be. The larger the COERCIVE FORCE, the more permanent the RESIDUAL INDUCTION is supposed to be with time, and vice versa. By many skilled in the art the product of RESIDUAL INDUCTION and COERCIVE FORCE is considered an excellent criterion of the strength of the magnet.

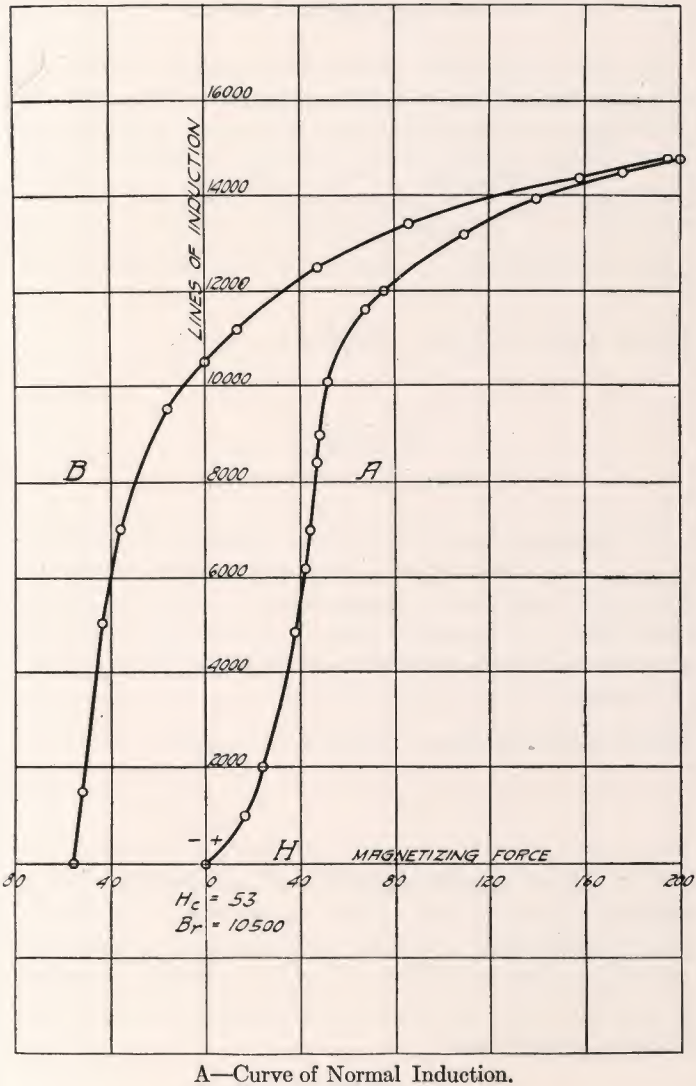
The curves shown on the graph are explained as follows:

In the diagram curve "A" represents the relation between field strength and magnetism taken up by the sample bar when the steel is tested after first being totally demagnetized.

Curve " B " represents one-quarter of the hysteresis loop which is taken after the steel has been magnetized to the field strength shown.

The above curves depict the average obtained over a long series of tests of our chrome magnet steel and can be regarded as a good average magnetic value of our Yuma chrome magnet steel

MAGNETIZATION CURVES OF CHROMIUM MAGNET STEEL



A—Curve of Normal Induction.
B—Hysteresis Loop.

ATSINA

TUNGSTEN MAGNET STEEL

We have, after many experiments, evolved a brand of Tungsten Magnet Steel which has higher coercive values and greater permanency than any other type of permanent magnet steel. ATSINA carries a correct percentage of alloys, is of great purity and is extremely homogeneous. Great care has been exercised in its manufacture so as to completely insure the desired micro-structure. This steel will harden without any tendency to check, crack, or warp.

HEAT TREATMENT: *Supplied on request.*

YUMA

CHROME MAGNET STEEL

Our Chrome Magnet Steel which has been developed for use as a permanent magnet will show practically no loss in permanency after the first ageing period. YUMA has greater coercive force and permanence than any other type of chrome magnet steel. It will harden very readily and is free from any tendency to crack, check, or warp.

HEAT TREATMENT: *Supplied on request*

Our ATSINA tungsten magnet steel has somewhat better magnetic properties than chrome magnet steel. We recommend the use of our YUMA chrome magnet steel as being easy to work, and less in first cost. If sufficient weight of magnet is used, this more than offsets the extra magnetic values of the tungsten magnet steel.

Standard Tables and General Information

USEFUL INFORMATION

To find the area of a circle, multiply the square of the diameter by .7854

To find the diameter of a circle, multiply the circumference by .31831

To find the circumference of a circle, multiply the diameter by 3.1416.

To find the area of an octagon, multiply the square of the diameter of the inscribed circle by .828.

To find the area of a hexagon, multiply the square of the diameter of the inscribed circle by .866.

To find the area of a triangle, multiply the base by one-half the perpendicular height.

To find the area of a trapezoid, add the two parallel sides together and multiply the sum by half the perpendicular distance between them.

To find the area of the section of a flat bar, or the area of a rectangle, multiply the width by the thickness.

To find the number of cubic inches in any bar, multiply the area of its section in inches by its length in inches.

A British thermal unit (B. t. u.) is the heat required to raise the temperature of one pound of water one degree Fahrenheit

A foot pound is the amount of work required to raise one pound through a distance of one foot.

A horse power (h. p.) is equal to 33,000 foot pounds per minute or 550 foot pounds per second. One horse power equals .746 kilowatts and is equivalent to 42.41 B. t. u. per minute

The weight of one cubic foot of steel is approximately 490 pounds.

The weight of one cubic inch of steel is approximately .285 pound.

The specific gravity of steel is approximately 7.85, while that of grey cast-iron averages 7.22, and white iron 7.65.

Having the number of cubic inches in any bar, to find its weight in carbon steel, multiply by .2833 if exact weight is desired; or multiply by .3 if a practical weight is wanted. For the weight of wrought iron, multiply the cubic inches by .28. For the weight of cast iron, multiply the cubic inches by .26

Steels of the high speed types are much heavier than ordinary tool steel. Thus while the specific gravity of ordinary tool steel is 7.85, that of high speed steels varies from 8.45 to 8.75, depending upon the percentage of chromium and tungsten present. In estimating weights of high speed bars, therefore, one must increase the weights as given for ordinary steel by from 12 to 14 per cent. In general, one may consider high speed steel as 13 per cent heavier than tool steel.

WEIGHT OF STEEL

BARS

For hot-worked steel of .50 per cent carbon:

One cubic inch weighs 0.2833 pounds.

One cubic foot weighs 489.54 pounds.

Specific gravity 7.854.

For Mohawk Extra high speed steel, add 13 per cent.

The tables of weights for hot-worked straight carbon bar steel are calculated from the unit, 1 cubic inch = 0.2833 pound or its equivalent 1 cubic foot = 489.54 pounds. A convenient unit much used in practise is 1 cubic inch = 0.3 pound, which gives weights about 6 per cent heavier than those in the tables Since bar-steel is usually furnished slightly full to size, weights calculated on this approximate basis yield fairly close working results for all except very large sizes.

The weight per foot of Octagon Steel is found by multiplying the weight per foot of a Round Bar of the same size by 1.0547.

The weight per foot of Hexagon Steel is found by multiplying the weight per foot of a Round Bar of the same size by 1.1026.

STRIPS AND WIRE

Cold-rolled and drawn steel weighs slightly less than hot-rolled or hammered steel: 1 cubic inch weighs 0.28313 pound. Specific gravity 7.848.

To figure approximately the weight of Cold-Rolled Steel or Flat Wires:

Divide the thickness, in thousandths of an inch, by 300; the quotient will be the weight per foot of a strip 1 inch wide. Or divide by 25; the quotient will be the weight of one square foot.

HIGH SPEED STEEL

ROUND SQUARE

SIZE	Weight of Rounds		Weight of Squares	
	Per Inch	Per Foot	Per Inch	Per Foot
1/16	.00098	.01176	.0013	.015
1/8	.0039	.0468	.005	.060
3/16	.0088	.1056	.0113	.135
1/4	.0156	.1872	.020	.241
5/16	.0244	.2928	.031	.376
3/8	.0352	.4224	.045	.541
7/16	.0478	.5736	.061	.737
1/2	.0625	.7500	.080	.962
9/16	.0791	.9492	.101	1.217
5/8	.0976	1.1712	.125	1.503
11/16	.118	1.416	.151	1.818
3/4	.141	1.692	.180	2.164
13/16	.165	1.980	.212	2.540
7/8	.191	2.292	.245	2.945
15/16	.219	2.628	.282	3.382
1	.248	2.976	.321	3.848
1 1/16	.281	3.372		
1 1/8	.315	3.780	.406	4.869
1 3/16	.349	4.188		
1 1/4	.397	4.764	.501	6.012
1 5/16	.427	5.124		
1 3/8	.472	5.664	.623	7.477
1 7/16	.517	6.204		
1 1/2	.562	6.744	.721	8.657
1 9/16	.607	7.284		
1 5/8	.663	7.956	.847	10.160
1 11/16	.709	8.508		
1 3/4	.765	9.180	.982	11.783
1 13/16	.821	9.852		
1 7/8	.877	10.524	1.127	13.526
1 15/16	.933	11.196		
2	1.001	12.012	1.282	15.390
2 1/16	1.057	12.684		
2 1/8	1.125	13.500	1.448	17.373
2 3/16	1.192	14.304		
2 1/4	1.271	15.252	1.623	19.478
2 5/16	1.338	16.056		
2 3/8	1.406	16.872	1.819	21.702

HIGH SPEED STEEL

Continued

ROUND SQUARE

SIZE	Weight of Rounds		Weight of Squares	
	Per inch	Per Foot	Per Inch	Per Foot
2 7/16	1.496	17.942		
2 1/2	1.563	18.756	2.003	24.04
2 9/16	1.642	19.704		
2 5/8	1.721	20.652	2.210	26.50
2 11/16	1.811	21.732		
2 3/4	1.890	22.680	2.340	29.09
2 13/16	1.980	23.760		
2 7/8	2.070	24.840	2.650	31.80
2 15/16	2.160	25.920		
3	2.250	27.000	2.890	34.63
3 1/16	2.340	28.080		
3 1/8	2.441	29.292	3.132	37.58
3 3/16	2.542	30.504		
3 1/4	2.643	31.810	3.386	40.64
3 5/16	2.745	32.940		
3 3/8	2.846	34.152	3.65	43.82
3 7/16	2.958	35.496		
3 1/2	3.060	36.720	3.93	47.13
3 9/16	3.172	38.064		
3 5/8	3.285	39.420	4.21	50.56
3 11/16	3.397	40.764		
3 3/4	3.521	42.252	4.51	54.10
3 13/16	3.633	43.596		
3 7/8	3.757	45.084	4.82	57.77
3 15/16	3.881	46.572		
4	4.005	48.060	5.13	61.56
4 1/16	4.128	49.536		
4 1/8	4.252	51.024		
4 3/16	4.387	52.644		
4 1/4	4.511	54.132	5.79	69.49
4 5/16	4.646	55.752		
4 3/8	4.781	57.372		
4 7/16	4.927	59.124		
4 1/2	5.062	60.744	6.50	77.91
4 9/16	5.208	62.496		
4 5/8	5.343	64.116		
4 11/16	5.490	65.880		
4 3/4	5.636	67.632	7.23	86.81
4 13/16	5.793	69.516		

HIGH SPEED STEEL

Concluded

ROUND SQUARE

SIZE	Weight of Rounds		Weight of Squares	
	Per inch	Per Foot	Per Inch	Per Foot
4⅞	5.940	71.280		
4 15/16	6.097	73.164		
5	6.255	75.060	8.02	96.19
5 1/16	6.412	76.944		
5⅛	6.570	78.840		
5 3/16	6.727	80.724		
5¼	6.890	82.752	8.84	106.04
5 5/16	7.053	84.646		
5⅜	7.222	86.664		
5 7/16	7.391	88.692		
5½	7.560	90.720	9.70	116.38
5 9/16	7.740	92.880		
5⅝	7.908	94.896		
5 11/16	8.088	97.056		
5¾	8.268	99.216	10.60	127.20
5 13/16	8.448	101.376		
5⅞	8.628	103.536		
5 15/16	8.820	105.840		
6	9.000	108.000	11.54	138.51
6⅛	9.382	112.584		
6¼	9.765	117.180		
6⅜	10.16	121.92		
6½	10.56	126.72		
6⅝	10.98	131.76		
6¾	11.36	136.32		
6⅞	11.81	141.72		
7½	12.26	147.12	15.71	188.53
7⅛	12.71	152.52		
7¼	13.16	157.92		
7⅜	13.61	163.32		
7½	14.06	168.72		
7⅝	14.51	174.12		
7¾	14.96	179.52		
7⅞	15.92	186.24		
8	16.08	192.96	20.52	246.24
9			25.97	311.65
10			32.06	384.75
11			38.80	465.55
12			46.17	554.04

HIGH SPEED STEEL

WEIGHTS OF FLATS

POUNDS PER INCH

Size, ins.	½″	⅝″	¾″	⅞″	1″	1⅛″	1¼″	1⅜″	1½″	1¾″
⅛	.020	.024	.030	.035	.040	.045	.050	.055	.060	.070
3/16	.030	.037	.045	.052	.060	.067	.074	.082	.090	.105
¼	.040	.050	.060	.070	.080	.090	.100	.110	.120	.146
5/16	.050	.062	.075	.087	.099	.113	.123	.137	.150	.174
⅜	.060	.075	.090	.105	.120	.134	.150	.164	.180	.209
7/16	.070	.088	.105	.122	.140	.157	.174	.193	.207	.243
½	.....	.100	.120	.140	.160	.180	.200	.220	.240	.280
9/16	.....	.113	.135	.157	.180	.202	.224	.247	.270	.314
⅝	.....	.....	.150	.174	.200	.224	.250	.274	.300	.350
11/16	.....	.....	.165	.192	.220	.247	.274	.302	.330	.383
¾	.....	.....	.....	.218	.240	.270	.300	.330	.360	.418
13/16	.....	.....	.....	.226	.260	.296	.323	.357	.390	.453
⅞	.....	.....	.....	.....	.280	.313	.350	.383	.418	.490
15/16	.....	.....	.....	.....	.300	.337	.373	.411	.448	.523
1	.....	.....	.....	.....	.....	.358	.398	.440	.478	.560
1⅛	.....	.....	.....	.....	.....	.....	.448	.494	.538	.630
1¼	.....	.....	.....	.....	.....	.....	.....	.548	.598	.698
1½	.....	.....	.....	.....	.....	.....	.....	.660	.720	.838

POUNDS PER FOOT

Size, ins.	½″	⅝″	¾″	⅞″	1″	1⅛″	1¼″	1⅜″	1½″	1¾″
⅛	.240	.299	.360	.419	.479	.538	.596	.658	.720	.838
3/16	.359	.448	.540	.628	.719	.808	.889	.988	1.08	1.26
¼	.478	.599	.720	.836	.959	1.08	1.19	1.31	1.44	1.68
5/16	.597	.747	.900	1.04	1.19	1.35	1.48	1.64	1.80	2.09
⅜	.718	.897	1.08	1.26	1.44	1.61	1.79	1.97	2.15	2.51
7/16	.837	1.05	1.26	1.46	1.68	1.88	2.09	2.31	2.48	2.92
½	.....	1.20	1.44	1.68	1.91	2.15	2.40	2.63	2.87	3.35
9/16	.....	1.35	1.62	1.88	2.15	2.42	2.69	2.96	3.23	3.77
⅝	.....	.....	1.80	2.09	2.39	2.69	2.99	3.29	3.59	4.19
11/16	.....	.....	1.98	2.30	2.63	2.96	3.29	3.62	3.95	4.60
¾	.....	.....	.....	2.51	2.87	3.22	3.59	3.94	4.31	5.02
13/16	.....	.....	.....	2.71	3.11	3.50	3.88	4.28	4.66	5.43
⅞	.....	.....	.....	.....	3.35	3.76	4.19	4.60	5.02	5.86
15/16	.....	.....	.....	.....	3.59	4.04	4.48	4.93	5.38	6.28
1	.....	.....	.....	.....	.....	4.30	4.78	5.27	5.74	6.71
1⅛	.....	.....	.....	.....	.....	.....	5.38	5.93	6.46	7.55
1¼	.....	.....	.....	.....	.....	.....	.....	6.58	7.18	8.38
1½	.....	.....	.....	.....	.....	.....	.....	7.90	8.63	10.06

HIGH SPEED STEEL

WEIGHTS OF FLATS

POUNDS PER INCH—(Continued)

Size, ins.	2″	2¼″	2½″	2¾″	3″	3½″	4″	5″	6″	7″
⅛	.080	.090	.100	.110	.120	.140	.160	.200	.240	.280
3/16	.120	.134	.150	.165	.180	.210	.240	.300	.360	.420
¼	.160	.180	.200	.220	.240	.280	.320	.400	.480	.560
5/16	.200	.224	.250	.273	.300	.350	.400	.500	.600	.700
⅜	.240	.270	.300	.330	.360	.420	.495	.600	.718	.836
7/16	.280	.320	.350	.383	.420	.490	.558	.700	.836	.975
½	.320	.360	.400	.440	.480	.558	.638	.800	.957	1.12
9/16	.360	.403	.450	.493	.540	.627	.718	.900	1.08	1.26
⅝	.400	.450	.500	.550	.600	.700	.800	1.000	1.20	1.40
11/16	.440	.493	.550	.603	.657	.767	.877	1.10	1.31	1.54
¾	.480	.540	.600	.660	.718	.836	.957	1.20	1.43	1.68
13/16	.520	.583	.650	.713	.778	.907	1.04	1.30	1.56	1.81
⅞	.560	.630	.700	.770	.840	.977	1.12	1.40	1.67	1.95
15/16	.598	.673	.750	.823	.897	1.05	1.20	1.50	1.80	2.10
1	.638	.718	.800	.878	.957	1.12	1.28	1.60	1.91	2.23
1⅛	.718	.808	.900	.988	1.08	1.26	1.44	1.80	2.15	2.51
1¼	.797	.898	.998	1.10	1.20	1.40	1.60	2.00	2.40	2.80
1½	.957	1.08	1.21	1.32	1.43	1.68	1.91	2.40	2.79	3.35

POUNDS PER FOOT—(Continued)

Size, ins.	2″	2¼″	2½″	2¾″	3″	3½″	4″	5″	6″	7″
⅛	.956	1.07	1.20	1.33	1.44	1.68	1.91	2.40	2.88	3.35
3/16	1.44	1.61	1.80	1.98	2.16	2.52	2.87	3.60	4.31	5.03
¼	1.91	2.15	2.40	2.63	2.88	3.35	3.82	4.79	5.75	6.70
5/16	2.40	2.69	2.99	3.28	3.59	4.18	4.78	5.98	7.18	8.37
⅜	2.87	3.23	3.60	3.95	4.31	5.02	5.74	7.20	8.62	10.03
7/16	3.35	3.77	4.19	4.60	5.02	5.86	6.69	8.37	10.03	11.70
½	3.83	4.31	4.79	5.26	5.74	6.70	7.65	9.59	11.48	13.40
9/16	4.31	4.84	5.38	5.92	6.46	7.52	8.61	10.75	12.94	15.08
⅝	4.79	5.39	5.99	6.59	7.19	8.37	9.59	11.97	14.38	16.76
11/16	5.26	5.92	6.57	7.23	7.89	9.20	10.52	13.16	15.75	18.48
¾	5.74	6.46	7.20	7.90	8.61	10.03	11.48	14.40	17.21	20.14
13/16	6.22	7.00	7.77	8.55	9.33	10.88	12.50	15.53	18.68	21.71
⅞	6.71	7.54	8.39	9.21	10.06	11.72	13.41	16.79	20.12	23.40
15/16	7.18	8.07	8.97	9.87	10.76	12.60	14.40	17.90	21.50	25.20
1	7.65	8.62	9.59	10.53	11.48	13.41	15.30	19.17	22.95	26.78
1⅛	8.61	9.69	10.79	11.86	12.92	15.09	17.21	21.57	25.82	30.15
1¼	9.56	10.77	11.98	13.17	14.36	16.76	19.13	23.96	28.81	33.48
1½	11.48	12.93	14.48	15.80	17.21	20.12	22.95	28.76	33.43	40.16

CARBON AND ALLOY STEEL

ROUND OCTAGON
SQUARE HEXAGON
WEIGHT PER FOOT

Size	Round	Square	Octagon	Hexagon
1/8	.042	.053	.04	.05
3/16	.094	.120	.10	.10
1/4	.167	.213	.18	.18
5/16	.261	.332	.28	.29
3/8	.376	.478	.40	.41
7/16	.511	.651	.54	.56
1/2	.668	.850	.70	.74
9/16	.845	1.076	.89	.93
5/8	1.043	1.328	1.10	1.15
11/16	1.262	1.607	1.33	1.40
3/4	1.502	1.913	1.58	1.66
13/16	1.763	2.245	1.86	1.94
7/8	2.044	2.603	2.16	2.25
15/16	2.347	2.989	2.48	2.59
1	2.670	3.400	2.82	2.94
1 1/8	3.379	4.303	3.56	3.73
1 1/4	4.173	5.312	4.40	4.60
1 3/8	5.049	6.428	5.29	5.54
1 1/2	6.008	7.650	6.34	6.63
1 5/8	7.051	8.978	7.44	7.78
1 3/4	8.178	10.41	8.64	9.02
1 7/8	9.388	11.95	9.90	10.36
2	10.68	13.60	11.26	11.78
2 1/8	12.06	15.35	12.71	13.30
2 1/4	13.52	17.22	14.26	14.91
2 3/8	15.07	19.18	15.88	16.62
2 1/2	16.69	21.25	17.60	18.41

NOTE:—For weight of high speed steel add 13%, or see special tables.

CARBON AND ALLOY STEEL

ROUND OCTAGON
SQUARE HEXAGON

WEIGHT PER FOOT
Continued

Size	Round	Square	Octagon	Hexagon
2⅝	18.40	23.43	19.41	20.30
2¾	20.20	25.71	21.28	22.28
2⅞	22.07	28.10	23.28	24.34
3	24.03	30.60	25.36	26.51
3⅛	26.08	33.20	27.50	28.77
3¼	28.20	35.92	29.74	31.10
3⅜	30.42	38.73	32.10	33.55
3½	32.71	41.65	34.50	36.08
3⅝	35.09	44.68	37.01	38.70
3¾	37.56	47.82	39.61	41.43
4	42.73	54.40	45.07	47.13
4¼	48.24	61.41	50.88	53.21
4½	54.07	68.85	57.03	59.64
4¾	60.25	76.71	63.55	66.46
5	66.76	85.00	70.41	73.64
5¼	73.60	93.72	77.63	81.18
5½	80.77	102.80	85.19	89.09
5¾	88.29	112.40	93.12	97.38
6	96.14	122.40	101.45	106.04
6½	112.8	143.6	119.0	124.42
7	130.9	166.6	138.1	144.38
8	171.0	217.6	180.48	188.61
9	216.3	275.4	228.1	238.58
10	267.0	340.0	281.6	294.50
11	323.1	411.4	340.6	356.38
12	384.5	489.6	405.8	428.64

NOTE:—For weight of high speed steel add 13 per cent, or see special tables.

CARBON AND ALLOY STEEL

Weights of Flats

POUNDS PER FOOT

	½	⅝	¾	⅞	1	1⅛	1¼	1⅜
1/16	.1060	.1381	.1594	.1859	.212	.2391	.2656	.292
⅛	.2125	.2656	.3188	.3720	.425	.4782	.5312	.585
3/16	.319	.399	.478	.558	.638	.717	.797	.875
¼	.425	.531	.636	.743	.850	.957	1.06	1.17
5/16	.531	.664	.797	.929	1.06	1.20	1.33	1.46
⅜	.638	.797	.957	1.116	1.28	1.43	1.59	1.76
7/16	.744	.929	1.116	1.302	1.49	1.68	1.86	2.05
½	.850	1.06	1.275	1.487	1.70	1.92	2.12	2.34
9/16	.957	1.20	1.434	1.674	1.92	2.15	2.39	2.63
⅝	1.06	1.33	1.594	1.859	2.12	2.39	2.65	2.92
11/16	1.17	1.46	1.753	2.045	2.34	2.63	2.92	3.22
¾	1.28	1.60	1.913	2.232	2.55	2.87	3.19	3.51
13/16	1.38	1.73	2.072	2.417	2.76	3.11	3.45	3.80
⅞	1.49	1.86	2.232	2.604	2.98	3.35	3.72	4.09
15/16	1.60	1.99	2.391	2.789	3.19	3.59	3.99	4.39
1	1.70	2.13	2.55	2.98	3.40	3.83	4.25	4.68
1⅛	1.91	2.39	2.87	3.35	3.83	4.30	4.78	5.26
1¼	2.12	2.66	3.19	3.72	4.25	4.79	5.31	5.85
1⅜	2.34	2.92	3.51	4.09	4.67	5.26	5.84	6.43
1½	2.55	3.19	3.83	4.47	5.10	5.74	6.38	7.02
1⅝	2.76	3.45	4.15	4.84	5.52	6.22	6.90	7.60
1¾	2.98	3.72	4.47	5.21	5.95	6.70	7.44	8.19
1⅞	3.19	3.99	4.79	5.58	6.38	7.17	7.97	8.77
2	3.40	4.25	5.10	5.95	6.80	7.65	8.50	9.35

NOTE:—For weight of high-speed steel add 13%, or see special tables.

CARBON AND ALLOY STEEL

Weights of Flats

POUNDS PER FOOT

Continued

	1½	1⅝	1¾	2	2¼	2½	2¾	3
1/16	.319	.346	.372	.425	.478	.531	.584	.638
⅛	.638	.692	.744	.850	.96	1.06	1.17	1.28
3/16	.957	1.04	1.15	1.28	1.44	1.59	1.75	1.91
¼	1.28	1.38	1.49	1.70	1.92	2.12	2.34	2.55
5/16	1.59	1.73	1.86	2.12	2.39	2.65	2.92	3.19
⅜	1.92	2.08	2.23	2.55	2.87	3.19	3.51	3.83
7/16	2.23	2.42	2.60	2.98	3.35	3.72	4.09	4.46
½	2.55	2.72	2.98	3.40	3.83	4.25	4.67	5.10
9/16	2.87	3.11	3.35	3.83	4.30	4.78	5.26	5.74
⅝	3.19	3.46	3.72	4.25	4.78	5.31	5.84	6.38
11/16	3.51	3.80	4.09	4.67	5.26	5.84	6.43	7.02
¾	3.83	4.15	4.47	5.10	5.75	6.38	7.02	7.65
13/16	4.14	4.49	4.84	5.53	6.21	6.90	7.60	8.29
⅞	4.47	4.84	5.20	5.95	6.69	7.44	8.18	8.93
15/16	4.78	5.18	5.58	6.38	7.18	7.97	8.77	9.57
1	5.10	5.53	5.95	6.80	7.65	8.50	9.35	10.20
1⅛	5.74	6.22	6.70	7.65	8.61	9.57	10.52	11.48
1¼	6.38	6.91	7.44	8.50	9.57	10.63	11.69	12.75
1⅜	7.02	7.60	8.18	9.35	10.52	11.69	12.85	14.03
1½	7.65	8.29	8.93	10.20	11.48	12.75	14.03	15.30
1⅝	8.29	8.98	9.67	11.05	12.43	13.81	15.19	16.58
1¾	8.93	9.67	10.42	11.90	13.40	14.88	16.37	17.85
1⅞	9.57	10.36	11.15	12.75	14.34	15.94	17.53	19.13
2	10.20	11.05	11.90	13.60	15.30	17.00	18.70	20.40

NOTE:—For weight of high-speed steel add 13%, or see special tables.

CARBON AND ALLOY STEEL

Weights of Flats

POUNDS PER FOOT

Continued

	3¼	3½	3¾	4	4¼	4½	4¾	5
1/16	.691	.741	.80	.85	.90	.96	1.01	1.06
1/8	1.38	1.49	1.59	1.70	1.81	1.91	2.02	2.13
3/16	2.07	2.23	2.39	2.55	2.71	2.87	3.03	3.19
1/4	2.76	2.98	3.19	3.40	3.61	3.83	4.04	4.25
5/16	3.45	3.72	3.99	4.25	4.52	4.78	5.05	5.31
3/8	4.15	4.47	4.78	5.10	5.42	5.74	6.06	6.38
7/16	4.83	5.20	5.58	5.95	6.32	6.70	7.07	7.44
1/2	5.53	5.95	6.38	6.80	7.22	7.65	8.08	8.50
9/16	6.22	6.70	7.17	7.65	8.13	8.61	9.09	9.57
5/8	6.91	7.44	7.97	8.50	9.03	9.57	10.10	10.63
11/16	7.60	8.18	8.76	9.35	9.93	10.52	11.11	11.69
3/4	8.29	8.93	9.57	10.20	10.84	11.48	12.12	12.75
13/16	8.98	9.67	10.36	11.05	11.74	12.43	13.12	13.81
7/8	9.67	10.41	11.16	11.90	12.65	13.39	14.13	14.87
15/16	10.36	11.16	11.95	12.75	13.55	14.34	15.14	15.94
1	11.05	11.90	12.75	13.60	14.45	15.30	16.15	17.00
1⅛	12.43	13.39	14.34	15.30	16.26	17.22	18.17	19.13
1¼	13.81	14.87	15.94	17.00	18.06	19.13	20.19	21.25
1⅜	15.20	16.36	17.53	18.70	19.87	21.04	22.21	23.38
1½	16.58	17.85	19.13	20.40	21.68	22.95	24.23	25.50
1⅝	17.96	19.34	20.72	22.10	23.48	24.87	26.25	27.63
1¾	19.34	20.83	22.32	23.80	25.29	26.78	28.27	29.75
1⅞	20.72	22.31	23.91	25.50	27.10	28.69	30.28	31.87
2	22.10	23.80	25.50	27.20	28.90	30.60	32.30	34.00

NOTE:—For weight of high-speed steel add 13%, or see special tables.

CARBON AND ALLOY STEEL

Weights of Flats

POUNDS PER FOOT

Concluded

	5¼	5½	5¾	6	6¼	6½	6¾	7
1/16	1.12	1.17	1.22	1.27	1.33	1.38	1.43	1.49
⅛	2.23	2.34	2.44	2.55	2.66	2.76	2.87	2.97
3/16	3.35	3.51	3.67	3.83	3.99	4.14	4.30	4.46
¼	4.46	4.67	4.89	5.10	5.31	5.53	5.74	5.95
5/16	5.58	5.84	6.11	6.38	6.64	6.90	7.17	7.44
⅜	6.69	7.02	7.34	7.65	7.97	8.29	8.61	8.93
7/16	7.81	8.18	8.56	8.93	9.29	9.67	10.04	10.41
½	8.93	9.35	9.77	10.20	10.63	11.05	11.48	11.90
9/16	10.04	10.52	11.00	11.48	11.95	12.43	12.91	13.39
⅝	11.16	11.69	12.22	12.75	13.28	13.81	14.34	14.87
11/16	12.27	12.85	13.44	14.03	14.61	15.20	15.78	16.36
¾	13.39	14.03	14.67	15.30	15.94	16.58	17.22	17.85
13/16	14.50	15.19	15.88	16.58	17.27	17.95	18.65	19.34
⅞	15.62	16.36	17.10	17.85	18.60	19.34	20.08	20.83
15/16	16.74	17.53	18.33	19.13	19.92	20.72	21.51	22.32
1	17.85	18.70	19.55	20.40	21.25	22.10	22.95	23.80
1⅛	20.08	21.04	21.99	22.95	23.91	24.87	25.82	26.78
1¼	22.32	23.38	24.44	25.50	26.56	27.62	28.69	29.75
1⅜	24.54	25.71	26.88	28.05	29.22	30.39	31.56	32.72
1½	26.78	28.05	29.33	30.60	31.88	33.15	34.43	35.70
1⅝	29.01	30.39	31.77	33.15	34.53	35.91	37.99	38.67
1¾	31.24	32.73	34.22	35.70	37.19	38.68	40.17	41.65
1⅞	33.47	35.06	36.65	38.25	38.85	41.44	43.03	44.63
2	35.70	37.40	39.10	40.80	42.50	44.20	45.90	47.60

NOTE:—For weight of high-speed steel add 13%, or see special tables.

DISC WEIGHTS

Multiply the weights per foot of bar steel of the same diameter as disc by that value which represents the thickness of the disc desired. This gives the approximate weight of the disc in pounds and is sufficiently accurate for practical purposes.

DECIMAL EQUIVALENTS FRACTIONAL PARTS OF FOOT

Inches	0	1/8	1/4	3/8	1/2	5/8	3/4	7/8
0	.00	.01	.02	.03	.04	.05	.06	.07
1	.08	.09	.10	.12	.13	.14	.15	.16
2	.17	.18	.19	.20	.21	.22	.23	.24
3	.25	.26	.27	.28	.29	.30	.31	.32
4	.33	.34	.35	.36	.38	.39	.40	.41
5	.42	.43	.44	.45	.46	.47	.48	.49
6	.50	.51	.52	.53	.54	.55	.56	.57
7	.58	.59	.60	.62	.63	.64	.65	.66
8	.67	.68	.69	.70	.71	.72	.73	.74
9	.75	.76	.77	.78	.79	.80	.81	.82
10	.83	.84	.85	.87	.88	.89	.90	.91
11	.92	.93	.94	.95	.96	.97	.98	.99

HALF-ROUND, OVAL AND HALF-OVAL BAR STEEL

Half-round, Inch	Oval, Inch	Pounds per Foot	Half-oval, Inch	Pounds per Foot
3/8	3/8 x 3/16	.186	3/8 x 3/32	.093
7/16	7/16 x 7/32	.253	7/16 x 7/64	.127
1/2	1/2 x 1/4	.331	1/2 x 1/8	.165
5/8	5/8 x 5/16	.517	5/8 x 5/32	.259
3/4	3/4 x 3/8	.744	3/4 x 3/16	.372
7/8	7/8 x 7/16	1.013	7/8 x 7/32	.507
1	1 x 1/2	1.323	1 1/2 x 1/4	.662
1 1/8	1 1/8 x 9/16	1.624	1 1/8 x 9/32	.812
1 1/4	1 1/4 x 5/8	2.067	1 1/4 x 5/16	1.034

THERMOMETER SCALES

Freezing point = 32° Fahr. = 0° Cent.

Boiling point = 212° Fahr. = 100° Cent.

The Fahrenheit thermometer is generally used in the United States and the Centigrade thermometer in countries using the metric system. In many metallurgical treatises in English, however, Centigrade temperatures are also used.

To convert degrees Centigrade into degrees Fahrenheit, multiply by nine, divide the product by 5, and add 32.

To convert degrees Fahrenheit into degrees Centigrade first subtract 32, multiply the remainder by 5 and divide the product by 9

EXAMPLES

To find the equivalent in Fahrenheit degrees of 600 degrees Centigrade.

$$\text{Deg. Fahr.} = \frac{9 \times 600}{5} \text{ plus } 32 = 1112^\circ$$

To find the equivalent in Centigrade degrees of 1112 degrees Fahrenheit:

$$\text{Deg. Cent.} = \frac{(1112-32)\ 5}{9} = \frac{1080 \times 5}{9} = 600^\circ$$

TEMPERATURE CONVERSION TABLES

ALBERT SAUVEUR

—459.4 TO 0

C		F
—273	**—459.4**	
—268	**—450**	
—262	**—440**	
—257	**—430**	
—251	**—420**	
—246	**—410**	
—240	**—400**	
—234	**—390**	
—229	**—380**	
—223	**—370**	
—218	**—360**	
—212	**—350**	
—207	**—340**	
—201	**—330**	
—196	**—320**	
—190	**—310**	
—184	**—300**	
—179	**—290**	
—173	**—280**	
—169	**—273**	—459.4
—168	**—270**	—454
—162	**—260**	—436
—157	**—250**	—418
—151	**—240**	—400
—146	**—230**	—382
—140	**—220**	—364
—134	**—210**	—346
—129	**—200**	—328
—123	**—190**	—310
—118	**—180**	—292
—112	**—170**	—274
—107	**—160**	—256
—101	**—150**	—238
— 96	**—140**	—220
— 90	**—130**	—202
— 84	**—120**	—184
— 79	**—110**	—166
— 73	**—100**	—148
— 68	**— 90**	—130
— 62	**— 80**	—112
— 57	**— 70**	— 94
— 51	**— 60**	— 76
— 46	**— 50**	— 58
— 40	**— 40**	— 40
— 34	**— 30**	— 22
— 29	**— 20**	— 4
— 23	**— 10**	14
— 17.7	**0**	32

0 TO 100

C		F	C		F
—17.7	**0**	32	9.9	**50**	122.0
—17.2	**1**	33.8	10.4	**51**	123.8
—16.6	**2**	35.6	11.1	**52**	125.6
—16.1	**3**	37.4	11.5	**53**	127.4
—15.5	**4**	39.2	12.1	**54**	129.2
—15.0	**5**	41.0	12.6	**55**	131.0
—14.4	**6**	42.8	13.2	**56**	132.8
—13.9	**7**	44.6	13.7	**57**	134.6
—13.3	**8**	46.4	14.3	**58**	136.4
—12.7	**9**	48.2	14.8	**59**	138.2
—12.2	**10**	50.0	15.6	**60**	140.0
—11.6	**11**	51.8	16.1	**61**	141.8
—11.1	**12**	53.6	16.6	**62**	143.6
—10.5	**13**	55.4	17.1	**63**	145.4
—10.0	**14**	57.2	17.7	**64**	147.2
— 9.4	**15**	59.0	18.2	**65**	149.0
— 8.8	**16**	61.8	18.8	**66**	150.8
— 8.3	**17**	63.6	19.3	**67**	152.6
— 7.7	**18**	65.4	19.9	**68**	154.4
— 7.2	**19**	67.2	20.4	**69**	156.2
— 6.6	**20**	68.0	21.0	**70**	158.0
— 6.1	**21**	69.8	21.5	**71**	159.8
— 5.5	**22**	71.6	22.2	**72**	161.6
— 5.0	**23**	73.4	22.7	**73**	163.4
— 4.4	**24**	75.2	23.3	**74**	165.2
— 3.9	**25**	77.0	23.8	**75**	167.0
— 3.3	**26**	78.8	24.4	**76**	168.8
— 2.8	**27**	80.6	25.0	**77**	170.6
— 2.2	**28**	82.4	25.5	**78**	172.4
— 1.6	**29**	84.2	26.2	**79**	174.2
— 1.1	**30**	86.0	26.8	**80**	176.0
— .6	**31**	87.8	27.3	**81**	177.8
0	**32**	89.6	27.7	**82**	179.6
.5	**33**	91.4	28.2	**83**	181.4
1.1	**34**	93.2	28.8	**84**	183.2
1.6	**35**	95.0	29.3	**85**	185.0
2.2	**36**	96.8	29.9	**86**	186.8
2.7	**37**	98.6	30.4	**87**	188.6
3.3	**38**	100.4	31.0	**88**	190.4
3.8	**39**	102.2	31.5	**89**	192.2
4.4	**40**	104.0	32.1	**90**	194.0
4.9	**41**	105.8	32.6	**91**	195.8
5.5	**42**	107.6	33.3	**92**	197.6
6.0	**43**	109.4	33.8	**93**	199.4
6.6	**44**	111.2	34.4	**94**	201.2
7.1	**45**	113.0	34.9	**95**	203.0
7.7	**46**	114.8	35.5	**96**	204.8
8.2	**47**	116.6	36.1	**97**	206.6
8.8	**48**	118.4	36.6	**98**	208.4
9.3	**49**	120.2	37.1	**99**	210.2
			37.7	**100**	212.0

TEMPERATURE CONVERSION TABLES—Continued

100 TO 1000						1000 TO 1500		
C		F	C		F	C		F
38	100	212	260	500	932	538	1000	1832
43	110	230	265	510	950	543	1010	1850
49	120	248	271	520	968	549	1020	1868
54	130	266	276	530	986	554	1030	1886
60	140	284	282	540	1004	560	1040	1904
65	150	302	288	550	1022	565	1050	1922
71	160	320	293	560	1040	571	1060	1940
76	170	338	299	570	1058	576	1070	1958
83	180	356	304	580	1076	582	1080	1976
88	190	374	310	590	1094	587	1090	1994
93	200	392	315	600	1112	593	1100	2012
99	210	410	321	610	1130	598	1110	2030
100	212	413	326	620	1148	604	1120	2048
104	220	428	332	630	1166	609	1130	2066
110	230	446	338	640	1184	615	1140	2084
115	240	464	343	650	1202	620	1150	2102
121	250	482	349	660	1220	626	1160	2120
127	260	500	354	670	1238	631	1170	2138
132	270	518	360	680	1256	637	1180	2156
138	280	536	365	690	1274	642	1190	2174
143	290	554	371	700	1292	648	1200	2192
149	300	572	376	710	1310	653	1210	2210
154	310	590	382	720	1328	659	1220	2228
160	320	608	387	730	1346	664	1230	2246
165	330	626	393	740	1364	670	1240	2264
171	340	644	399	750	1382	675	1250	2282
177	350	662	404	760	1400	681	1260	2300
182	360	680	410	770	1418	686	1270	2318
188	370	698	415	780	1436	692	1280	2336
193	380	716	421	790	1454	697	1290	2354
199	390	734	426	800	1472	704	1300	2372
204	400	752	432	810	1490	708	1310	2390
210	410	770	438	820	1508	715	1320	2408
215	420	788	443	830	1526	719	1330	2426
221	430	806	449	840	1544	726	1340	2444
226	440	824	454	850	1562	734	1350	2462
232	450	842	460	860	1580	737	1360	2480
238	460	860	465	870	1598	741	1370	2498
243	470	878	471	880	1616	748	1380	2516
249	480	896	476	890	1634	752	1390	2534
254	490	914	482	900	1652	760	1400	2552
			487	910	1670	765	1410	2570
			493	920	1688	771	1420	2588
			498	930	1706	776	1430	2606
			504	940	1724	782	1440	2624
			510	950	1742	787	1450	2642
			515	960	1760	793	1460	2660
			520	970	1778	798	1470	2678
			526	980	1796	804	1480	2696
			532	990	1814	809	1490	2714
			538	1000	1832	815	1500	2732

TEMPERATURE CONVERSION TABLES—Concluded

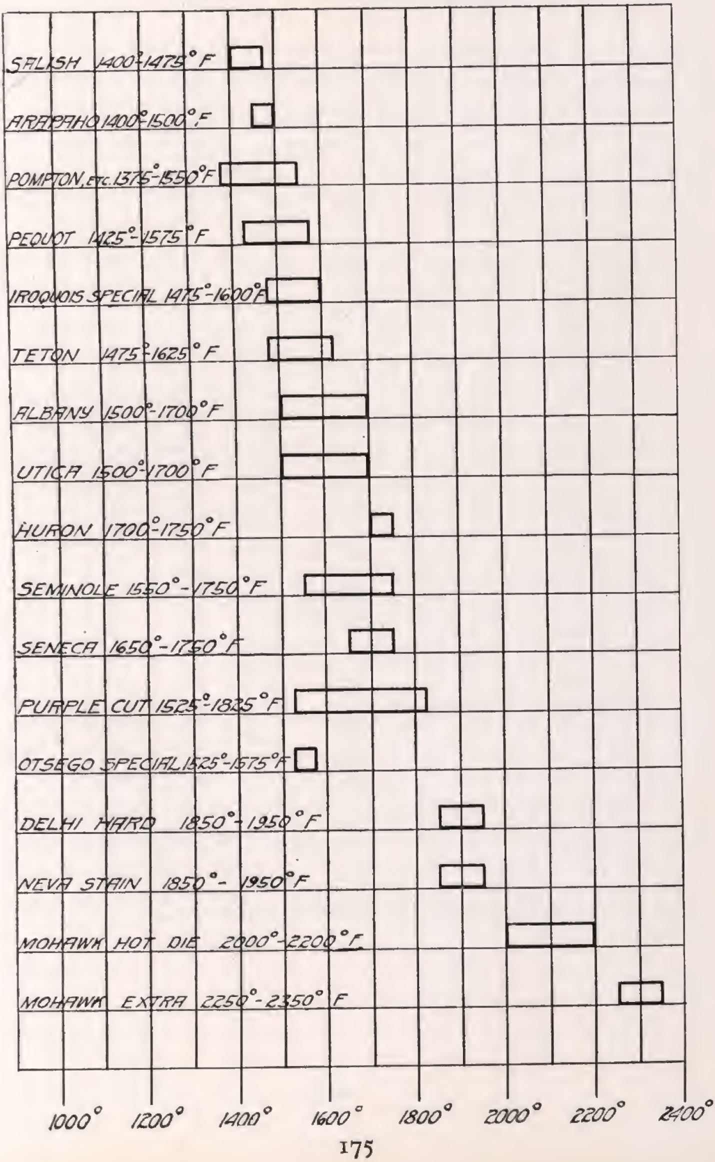
1500 TO 2000			2000 TO 3000					
C		F	C		F	C		F
815	**1500**	2732	1093	**2000**	3632	1371	**2500**	4532
820	**1510**	2750	1098	**2010**	3650	1376	**2510**	4550
827	**1520**	2768	1104	**2020**	3668	1382	**2520**	4568
831	**1530**	2786	1109	**2030**	3686	1387	**2530**	4586
838	**1540**	2804	1115	**2040**	3704	1393	**2540**	4604
842	**1550**	2822	1120	**2050**	3722	1398	**2550**	4622
849	**1560**	2840	1126	**2060**	3740	1404	**2560**	4640
853	**1570**	2858	1131	**2070**	3758	1409	**2570**	4658
860	**1580**	2876	1137	**2080**	3776	1415	**2580**	4676
864	**1590**	2894	1142	**2090**	3794	1420	**2590**	4694
871	**1600**	2912	1149	**2100**	3812	1427	**2600**	4712
876	**1610**	2930	1154	**2110**	3820	1432	**2610**	4730
882	**1620**	2948	1160	**2120**	3848	1438	**2620**	4748
887	**1630**	2966	1165	**2130**	3866	1443	**2630**	4766
893	**1640**	2984	1171	**2140**	3884	1449	**2640**	4784
898	**1650**	3002	1176	**2150**	3902	1454	**2650**	4802
904	**1660**	3020	1182	**2160**	3920	1460	**2660**	4820
909	**1670**	3038	1187	**2170**	3938	1465	**2670**	4838
915	**1680**	3056	1193	**2180**	3956	1471	**2680**	4856
920	**1690**	3074	1198	**2190**	3974	1476	**2690**	4874
926	**1700**	3092	1204	**2200**	3992	1483	**2700**	4892
931	**1710**	3110	1209	**2210**	4010	1488	**2710**	4910
937	**1720**	3128	1215	**2220**	4028	1494	**2720**	4928
942	**1730**	3146	1220	**2230**	4046	1499	**2730**	4946
948	**1740**	3164	1226	**2240**	4064	1505	**2740**	4964
953	**1750**	3182	1231	**2250**	4082	1510	**2750**	4982
959	**1760**	3200	1237	**2260**	4100	1516	**2760**	5000
964	**1770**	3218	1242	**2270**	4118	1521	**2770**	5018
970	**1780**	3236	1248	**2280**	4136	1527	**2780**	5036
975	**1790**	3254	1253	**2290**	4154	1532	**2790**	5054
981	**1800**	3272	1259	**2300**	4172	1538	**2800**	5072
986	**1810**	3290	1264	**2310**	4190	1543	**2810**	5090
992	**1820**	3308	1270	**2320**	4208	1549	**2820**	5108
997	**1830**	3326	1275	**2330**	4226	1554	**2830**	5126
1003	**1840**	3344	1281	**2340**	4244	1560	**2840**	5144
1008	**1850**	3362	1286	**2350**	4262	1565	**2850**	5162
1014	**1860**	3380	1292	**2360**	4280	1571	**2860**	5180
1019	**1870**	3398	1297	**2370**	4298	1576	**2870**	5198
1025	**1880**	3416	1303	**2380**	4316	1582	**2880**	5216
1030	**1890**	3434	1308	**2390**	4334	1587	**2890**	5234
1036	**1900**	3452	1315	**2400**	4352	1593	**2900**	5252
1041	**1910**	3470	1320	**2410**	4370	1598	**2910**	5270
1047	**1920**	3488	1326	**2420**	4388	1604	**2920**	5288
1052	**1930**	3506	1331	**2430**	4406	1609	**2930**	5306
1058	**1940**	3524	1337	**2440**	4424	1615	**2940**	5324
1063	**1950**	3542	1342	**2450**	4442	1620	**2950**	5342
1069	**1960**	3560	1348	**2460**	4460	1626	**2960**	5360
1074	**1970**	3578	1353	**2470**	4478	1631	**2970**	5378
1080	**1980**	3596	1359	**2480**	4496	1637	**2980**	5396
1085	**1990**	3614	1364	**2490**	4514	1642	**2990**	5414
1093	**2000**	3632				1649	**3000**	5432

NOTE:—The numbers in **Bold Face Type** refer to the temperature either in degrees Centigrade or Fahrenheit which it is desired to convert into the other scale. If converting from Fahrenheit degrees to Centigrade degrees the equivalent temperature will be found in the left column, while if converting from degrees Centrigrade to degrees Fahrenheit, the answer will be found in the column on the right.

TEMPERATURES AND COLORS AND THEIR RELATION TO STEEL TREATMENT

	Colors	Fahrenheit	Centigrade	Processes
Heat Colors	White	2500°	1371°	Welding
		2400°	1315°	High Speed Steel Hardening (2250°–2400° F)
	Yellow White	2300°	1259°	
		2200°	1204°	
		2100°	1149°	
	Yellow	2000°	1093°	
		1900°	1036°	Alloy Steel Hardening (1500°–1950° F)
	Orange Red	1800°	981°	
		1700°	926°	
		1600°	871°	
	Light Cherry Red			
		1500°	815°	Carbon Steel Hardening (1350°–1550° F)
	Cherry Red	1400°	760°	
		1300°	704°	
	Dark Red			
		1200°	648°	
		1100°	593°	High Speed Steel Tempering (350°–1100° F)
	Very Dark Red	1000°	538°	Carbon Steel Tempering (300°–1050° F)
		900°	482°	
	Black Red in dull light or darkness	800°	426°	
		700°	371°	
Temper Colors	Pale Blue (590° F)	600°	315°	
	Violet (545° F)			
	Purple (525° F)	500°	260°	
	Yellowish Brown (490° F)			
	Dark Straw (465° F)	400°	204°	
	Light Straw (425° F)			
		300°	149°	
		200°	93°	
		100°	38°	
		0°	0°	

LUDLUM STEELS — HARDENING RANGES



HARDNESS NUMERALS
BRINELL TEST

STEEL BALL OF 10 MM. DIAMETER

Diameter of Impression in MM.	Hardness Numeral Pressure in k'gs. 3000	500	Diameter of Impression in MM.	Hardness Numeral Pressure in k'gs. 3000	500	Diameter of Impression in MM.	Hardness Numeral Pressure in k'gs. 3000	500
2.00	946	158	3.65	277	46.2	5.30	126	21.
2.05	898	150	3.70	269	44.8	5.35	124	20.7
2.10	857	143	3.75	262	43.7	5.40	121	20.2
2.15	817	136	3.80	255	42.5	5.45	118	19.7
2.20	782	130	3.85	248	41.3	5.50	116	19.3
2.25	744	124	3.90	241	40.2	5.55	114	19.
2.30	713	119	3.95	235	39.2	5.60	112	18.7
2.35	683	114	4.00	228	38	5.65	109	18.2
2.40	652	109	4.05	223	37.2	5.70	107	17.8
2.45	627	105	4.10	217	36.2	5.75	105	17.5
2.50	600	100	4.15	212	35.3	5.80	103	17.2
2.55	578	96.3	4.20	207	34.5	5.85	101	16.8
2.60	555	92.5	4.25	202	33.7	5.90	99	16.5
2.65	532	88.7	4.30	196	32.7	5.95	97	16.2
2.70	512	85.3	4.35	192	32.	6.00	95	15.8
2.75	495	82.5	4.40	187	31.2	6.05	94	15.7
2.80	477	79.5	4.45	183	30.5	6.10	92	15.3
2.85	460	76.7	4.50	179	29.8	6.15	90	15.
2.90	444	74.0	4.55	174	29.	6.20	89	14.8
2.95	430	71.7	4.60	170	28.3	6.25	87	14.5
3.00	418	69.7	4.65	166	27.7	6.30	86	14.3
3.05	402	67.0	4.70	163	27.2	6.35	84	14.
3.10	387	64.5	4.75	159	26.5	6.40	82	13.7
3.15	375	62.5	4.80	156	26.	6.45	81	13.5
3.20	364	60.7	4.85	153	25.5	6.50	80	13.3
3.25	351	58.5	4.90	149	24.8	6.55	79	13.2
3.30	340	56.7	4.95	146	24.3	6.60	77	12.8
3.35	332	55.3	5.00	143	23.8	6.65	76	12.7
3.40	321	53.5	5.05	140	23.3	6.70	74	12.3
3.45	311	51.8	5.10	137	22.8	6.75	73	12.2
3.50	302	50.3	5.15	134	22.3	6.80	71	11.8
3.55	293	48.8	5.20	131	21.8	6.85	70	11.7
3.60	286	47.7	5.25	128	21.3	6.90	69	11.5
						6.95	68	11.3

NOTES.

All very hard materials such as iron, steel, etc. to be tested at a load of 3000 k'g. Softer materials to be tested at a load of 500 k'g. Numerals given $= \frac{P}{A}$ where P is the pressure in k'gs and A is the area of the impression in square millimeters.

In order to determine the ultimate strength of the specimen by this test it will be necessary to establish, by experiment, a coefficient by which to multiply the hardness numerals.

WIRE GAUGES

SIZES IN DECIMAL PARTS OF AN INCH

Number of Gage	American or Brown & Sharpe	Birmingham or Stubs Iron Wire	Washburn & Moen Mfg. Co.	Trenton Iron Co.	Stubs' Steel Wire	Imperial Wire Gage	U. S. Standard for Plate
000000	....	....	....	....	....	.464	.46875
00000	....	....	....	.450	....	.432	.4375
0000	.46	.454	.3938	.400	....	.400	.40625
000	.40964	.425	.3625	.360	....	.372	.375
00	.3648	.380	.3310	.330	....	.348	.34375
0	.32486	.340	.3065	.305	....	.324	.3125
1	.2893	.300	.2830	.285	.227	.300	.28125
2	.25763	.284	.2625	.265	.219	.276	.265625
3	.22942	.259	.2437	.245	.212	.252	.25
4	.20431	.238	.2253	.225	.207	.232	.234375
5	.18194	.220	.2070	.205	.204	.212	.21875
6	.16202	.203	.1920	.190	.201	.192	.203125
7	.14428	.180	.1770	.175	.199	.176	.1875
8	.12849	.165	.1620	.160	.197	.160	.171875
9	.11443	.148	.1483	.145	.194	.144	.15625
10	.10189	.134	.1350	.130	.191	.128	.140625
11	.090742	.120	.1205	.1175	.188	.116	.125
12	.080808	.109	.1055	.105	.185	.104	.109375
13	.071961	.095	.0915	.0925	.182	.092	.09375
14	.064084	.083	.0800	.080	.180	.080	.078125
15	.057068	.072	.0720	.070	.178	.072	.0703125
16	.05082	.065	.0625	.061	.175	.064	.0625
17	.045257	.058	.0540	.0525	.172	.056	.05625
18	.040303	.049	.0475	.045	.168	.048	.05
19	.03589	.042	.0410	.040	.164	.040	.04375
20	.031961	.035	.0348	.035	.161	.036	.0375
21	.028462	.032	.03175	.031	.157	.032	.034375
22	.025347	.028	.0286	.028	.155	.028	.03125
23	.022571	.025	.0258	.025	.153	.024	.028125
24	.0201	.022	.0230	.0225	.151	.022	.025
25	.0179	.020	.0204	.020	.148	.020	.021875
26	.01594	.018	.0181	.018	.146	.018	.01875
27	.014195	.016	.0173	.017	.143	.0164	.0171875
28	.012641	.014	.0162	.016	.139	.0149	.015625
29	.011257	.013	.0150	.015	.134	.0136	.0140625
30	.010025	.012	.0140	.014	.127	.0124	.0125
31	.008928	.010	.0132	.013	.120	.0116	.0109375
32	.00795	.009	.0128	.012	.115	.0108	.01015625
33	.00708	.008	.0118	.011	.112	.0100	.009375
34	.006304	.007	.0104	.010	.110	.0092	.00859375
35	.005614	.005	.0095	.0095	.108	.0084	.0078125
36	.005	.004	.0090	.009	.106	.0076	.00703125
37	.004453	....	....	.0085	.103	.0068	.006640625
38	.003965	....	....	.008	.101	.0060	.00625
39	.003531	....	....	.0075	.099	.0052	....
40	.003144	....	....	.007	.097	.0048	....

U.S. STANDARD GAUGE SHEET IRON AND STEEL

AS ESTABLISHED BY ACT OF CONGRESS 1893

Number of gage	Approximate thickness in fractions of an inch	Approximate thickness in decimal parts of an inch	Weight per square foot in pounds avoirdupois	Weight per square foot in kilograms
0000000	1/2	0.5	20.00	9.072
000000	15/32	.46875	18.75	8.505
00000	7/16	.4375	17.50	7.983
0000	13/32	.40625	16.25	7.371
000	3/8	.375	15.00	6.804
00	11/32	.34375	13.75	6.237
0	5/16	.3125	12.50	5.67
1	9/32	.28125	11.25	5.103
2	17/64	.265625	10.625	4.819
3	1/4	.25	10.00	4.536
4	15/64	.234375	9.375	4.252
5	7/32	.21875	8.75	3.969
6	13/64	.203125	8.125	3.685
7	3/16	.1875	7.5	3.402
8	11/64	.171875	6.875	3.118
9	5/32	.15625	6.25	2.835
10	9/64	.140625	5.625	2.552
11	1/8	.125	5.00	2.268
12	7/64	.109375	4.375	1.984
13	3/32	.09375	3.75	1.701
14	5/64	.078125	3.125	1.417
15	9/128	.0703185	2.8125	1.276
16	1/16	.0625	2.5	1.134
17	9/160	.05625	2.25	1.021
18	1/20	.05	2.00	.9072
19	7/160	.04375	1.75	.7988
20	3/80	.0375	1.50	.6804
21	11/320	.034375	1.375	.6237
22	1/32	.03125	1.25	.567
23	9/320	.028125	1.125	.5103
24	1/40	.025	1.00	.4536
25	7/320	.021875	.875	.3969
26	3/160	.01875	.75	.3402
27	11/640	.0171875	.6875	.3119
28	1/64	.015625	.625	.2835
29	9/640	.0140625	.5625	.2551
30	1/80	.0125	.5	.2268
31	7/640	.0109375	.4375	.1984
32	13/1280	.01015625	.40625	.1843
33	3/320	.009375	.375	.1701
34	11/1280	.00859375	.34375	.1559
35	5/640	.0078125	.3125	.1417
36	9/1280	.00703125	.28125	.1276
37	17/2560	.006640625	.265625	.1205
38	1/160	.00625	.25	.1134

AREAS AND CIRCUMFERENCES OF CIRCLES FROM 1 TO 12

Dia.	Area	Circum.	Dia.	Area	Circum.
1/32	0.00077	0.098175	9/16	1.9175	4.90874
3/64	0.00173	0.147262	5/8	2.0739	5.10509
1/16	0.00307	0.196350	11/16	2.2365	5.30144
3/32	0.00690	0.294524	3/4	2.4053	5.49779
1/8	0.01227	0.392699	13/16	2.5802	5.69414
5/32	0.01917	0.490874	7/8	2.7612	5.89049
3/16	0.02761	0.589049	15/16	2.9483	6.08684
7/32	0.03758	0.687223	2	3.1416	6.28319
1/4	0.04909	0.785398	1/16	3.3410	6.47953
9/32	0.06213	0.883573	1/8	3.5466	6.67588
5/16	0.07670	0.981748	3/16	3.7583	6.87223
11/32	0.09281	1.07992	1/4	3.9761	7.06858
3/8	0.11045	1.17810	5/16	4.2000	7.26493
13/32	0.12962	1.27627	3/8	4.4301	7.46128
7/16	0.15033	1.37445	7/16	4.6664	7.65763
15/32	0.17257	1.47262	1/2	4.9087	7.85398
1/2	0.19635	1.57080	9/16	5.1572	8.05033
17/32	0.22166	1.66897	5/8	5.4119	8.24668
9/16	0.24850	1.76715	11/16	5.6727	8.44303
19/32	0.27688	1.86532	3/4	5.9396	8.63938
5/8	0.30680	1.96350	13/16	6.2126	8.83573
21/32	0.33824	2.06167	7/8	6.4918	9.03208
11/16	0.37122	2.15984	15/16	6.7771	9.22843
23/32	0.40574	2.25802	3	7.0686	9.42478
3/4	0.44179	2.35619	1/16	7.3662	9.62113
25/32	0.47937	2.45437	1/8	7.6699	9.81748
13/16	0.51849	2.55254	3/16	7.9798	10.0138
27/32	0.55914	2.65072	1/4	8.2958	10.2102
7/8	0.60132	2.74889	5/16	8.6179	10.4065
29/32	0.64504	2.84707	3/8	8.9462	10.6029
15/16	0.69029	2.94524	7/16	9.2806	10.7992
31/32	0.73708	3.04342	1/2	9.6211	10.9956
1	0.78540	3.14159	9/16	9.9678	11.1919
1/16	0.88664	3.33794	5/8	10.321	11.3883
1/8	0.99402	3.53429	11/16	10.680	11.5846
3/16	1.1075	3.73064	3/4	11.045	11.7810
1/4	1.2272	3.92699	13/16	11.416	11.9773
5/16	1.3530	4.12334	7/8	11.793	12.1737
3/8	1.4849	4.31969	15/16	12.177	12.3700
7/16	1.6230	4.51604	4	12.566	12.5664
1/2	1.7671	4.71239	1/16	12.962	12.7627

AREAS AND CIRCUMFERENCES OF CIRCLES FROM 1 TO 12

Continued

Dia.	Area	Circum.	Dia.	Area	Circum.
1/8	13.364	12.9591	5/8	45.664	23.9546
3/16	13.772	13.1554	3/4	47.173	24.3473
1/4	14.186	13.3518	7/8	48.707	24.7400
5/16	14.607	13.5481	8	50.265	25.1327
3/8	15.033	13.7445	1/8	51.849	25.5224
7/16	15.466	13.9408	1/4	53.456	25.9181
1/2	15.904	14.1372	3/8	55.088	26.3108
9/16	16.349	14.3335	1/2	56.745	26.7035
5/8	16.800	14.5299	5/8	58.426	27.0962
11/16	17.257	14.7262	3/4	60.132	27.4889
3/4	17.721	14.9226	7/8	61.862	27.8816
13/16	18.190	15.1189	9	63.617	28.2743
7/8	18.665	15.3153	1/8	65.397	28.6670
15/16	19.147	15.5116	1/4	67.201	29.0597
5	19.635	15.7080	3/8	69.029	29.4524
1/16	20.129	15.9043	1/2	70.882	29.8451
1/8	20.629	16.1007	5/8	72.760	30.2378
3/16	21.135	16.2970	3/4	74.662	30.6305
1/4	21.648	16.4934	7/8	76.589	31.0232
5/16	22.166	16.6897	10	78.540	31.4159
3/8	22.691	16.8861	1/8	80.516	31.8086
7/16	23.221	17.0824	1/4	82.516	32.2013
1/2	23.758	17.2788	3/8	84.541	32.5940
9/16	24.301	17.4751	1/2	86.590	32.9867
5/8	24.850	17.6715	5/8	88.664	33.3794
11/16	25.406	17.8678	3/4	90.763	33.7721
3/4	25.967	18.0642	7/8	92.886	34.1648
13/16	26.535	18.2605	11	95.033	34.5575
7/8	27.109	18.4569	1/8	97.205	34.9502
15/16	27.688	18.6532	1/4	99.402	35.3429
6	28.274	18.8496	3/8	101.62	35.7356
1/8	29.465	19.2423	1/2	103.87	36.1283
1/4	30.680	19.6350	5/8	106.14	36.5210
3/8	31.919	20.0277	3/4	108.43	36.9137
1/2	33.183	20.4204	7/8	110.75	37.3064
5/8	34.472	20.8131	12	113.10	37.6991
3/4	35.785	21.2058	1/8	115.47	38.0918
7/8	37.122	21.5984	1/4	117.86	38.4845
7	38.485	21.9911	3/8	120.28	38.8772
1/8	39.871	22.3838	1/2	122.72	39.2699
1/4	41.282	22.7765	5/8	125.19	39.6626
3/8	42.718	23.1692	3/4	127.68	40.0553
1/2	44.179	23.5619	7/8	130.19	40.4480

FRACTIONS OF ONE INCH IN DECIMAL EQUIVALENTS

1/64	.0156		33/64	.5156	
1/32	.0313		17/32	.5313	
3/64	.0469		35/64	.5469	
1/16		.0625	9/16		.5625
5/64	.0781		37/64	.5781	
3/32	.0938		19/32	.5938	
7/64	.1094		39/64	.6094	
1/8		.1250	5/8		.6250
9/64	.1406		41/64	.6406	
5/32	.1563		21/32	.6563	
11/64	.1719		43/64	.6719	
3/16		.1875	11/16		.6875
13/64	.2031		45/64	.7031	
7/32	.2188		23/32	.7188	
15/64	.2344		47/64	.7344	
1/4		.2500	3/4		.7500
17/64	.2656		49/64	.7656	
9/32	.2813		25/32	.7813	
19/64	.2969		51/64	.7969	
5/16		.3125	13/16		.8125
21/64	.3281		53/64	.8281	
11/32	.3438		27/32	.8438	
23/64	.3594		55/64	.8594	
3/8		.3750	7/8		.8750
25/64	.3906		57/64	.8906	
13/32	.4063		29/32	.9063	
27/34	.4219		59/64	.9219	
7/16		.4375	15/16		.9375
29/64	.4531		61/64	.9531	
15/32	.4688		31/32	.9688	
31/64	.4844		63/64	.9844	
1/2		.5000	1		1.0000

U. S. OFFICIAL MILLIMETERS CONVERSION TABLE

Millimeters	Equivalent in Inches	Millimeters	Equivalent in Inches	Millimeters	Equivalent In inches
1	0.03937	34	1.33858	67	2.63779
2	0.07874	35	1.37795	68	2.67716
3	0.11811	36	1.41732	69	2.71653
4	0.15748	37	1.45669	70	2.75590
5	0.19685	38	1.49606	71	2.79527
6	0.23622	39	1.53543	72	2.83464
7	0.27559	40	1.57480	73	2.87401
8	0.31496	41	1.61417	74	2.91338
9	0.35433	42	1.65354	75	2.95275
10	0.39370	43	1.69291	76	2.99212
11	0.43307	44	1.73228	77	3.03149
12	0.47244	45	1.77165	78	3.07086
13	0.51181	46	1.81102	79	3.11023
14	0.55118	47	1.85039	80	3.14960
15	0.59055	48	1.88976	81	3.18897
16	0.62992	49	1.92913	82	3.22834
17	0.66929	50	1.96850	83	3.26771
18	0.70866	51	2.00787	84	3.30708
19	0.74803	52	2.04724	85	3.34645
20	0.78740	53	2.08661	86	3.38582
21	0.82677	54	2.12598	87	3.42519
22	0.86614	55	2.16535	88	3.46456
23	0.90551	56	2.20472	89	3.50393
24	0.94488	57	2.24409	90	3.54330
25	0.98425	58	2.28346	91	3.58267
26	1.02362	59	2.32283	92	3.62204
27	1.06299	60	2.36220	93	3.66141
28	1.10236	61	2.40157	94	3.70078
29	1.14173	62	2.44094	95	3.74015
30	1.18110	63	2.48031	96	3.77952
31	1.22047	64	2.51968	97	3.81889
32	1.25984	65	2.55905	98	3.85826
33	1.29921	66	2.59842	99	3.89763
				100	3.93700

METRIC CONVERSION FACTORS

1 gram	= 15,432 grains
1 meter	= 39.371 inches or 3.28083 feet
1 millimeter	= 0.03937 inch, or 1/25 in. approx.
1 metric ton, 1000 kilograms	= 2204.6 pounds or .9842 ton of 2240 pounds
1.016 metric ton, 1016 kilograms	= 1 ton of 2240 pounds

Unit	Inches to Milimeters	Millimeters to inches	Pounds to Kilograms	Kilograms to Pounds
1	25.4001	039371	0.45359	2.20462
2	50.8001	078742	0.90719	4.40924
3	76.2002	118112	1.36078	6.61386
4	101.6002	157483	1.81437	8.81849
5	127.0003	196854	2.26796	11.02311
6	152.4003	236225	2.72156	13.22773
7	177.8004	275596	3.17515	15.43235
8	203.2004	314966	3.62874	17.63697
9	228.6005	354337	4.08233	19.84159
10	254.0006	393708	4.35592	22.04622
11	279.4007	433079	4.98951	24.25084
12	304.8006	472450	5.44312	26.45546
13	330.2007	511821	5.89671	28.66008
14	355.6008	551192	6.35030	30.86470
15	381.0002	590563	6.80389	33.06932
16	406.4008	629932	7.25748	35.27394
17	431.8009	669303	7.71107	36.47856
18	457.2010	708674	8.16566	39.68318
19	482.6011	748045	8.61925	41.88780

1 kilogram per sq. centimeter = 14.2234 lbs. per sq. in.
1 kilogram per sq. millimeter = 1422.32 lbs. per sq. in.
1000 lbs. per sq. in. = 0.70308 kilograms per sq. mi. / 70.308 kilograms per sq. cm.

SOCIETY OF AUTOMOTIVE ENGINEERS

Steel Specifications

Chemical Compositions as Adopted March, 1923

CHROMIUM STEELS

S. A. E. Steel No.	Carbon Range	Manganese Range	Phosphorus, Max.	Sulphur, Max.	Chromium Range
5120	0.15–0.25	0.30–0.60	0.04	0.045	0.60–0.90
5140	0.35–0.45	0.50–0.80	0.04	0.045	0.80–1.10
5150	0.45–0.55	0.50–0.80	0.04	0.045	0.80–1.10
52100	0.95–1.10	0.20–0.50	0.03	0.030	1.20–1.50

CHROMIUM-VANADIUM STEELS

S. A. E. Steel No.	Carbon Range	Manganese Range	Phosphorus, Max.	Sulphur, Max.	Chromium Range	Vanadium	
						Min.	Desired
6120	0.15–0.25	0.50–0.80	0.04	0.04	0.80–1.10	0.15	0.18
6125	0.20–0.30	0.50–0.80	0.04	0.04	0.80–1.10	0.15	0.18
6130	0.25–0.35	0.50–0.80	0.04	0.04	0.80–1.10	0.15	0.18
6135	0.30–0.40	0.50–0.80	0.04	0.04	0.80–1.10	0.15	0.18
6140	0.35–0.45	0.50–0.80	0.04	0.04	0.80–1.10	0.15	0.18
6145	0.40–0.50	0.50–0.80	0.04	0.04	0.80–1.10	0.15	0.18
6150	0.45–0.55	0.50–0.80	0.04	0.04	0.80–1.10	0.15	0.18
6195	0.90–1.05	0.20–0.45	0.03	0.03	0.80–1.10	0.15	0.18

TUNGSTEN STEELS

S. A. E. Steel No.	Carbon Range	Manganese, Max.	Phosphorus, Max.	Sulphur, Max.	Chromium Range	Tungsten Range
71360	0.50–0.70	0.30	0.035	0.035	3.00–4.00	12.00–15.00
71660	0.50–0.70	0.30	0.035	0.035	3.00–4.00	15.00–18.00
7260	0.50–0.70	0.30	0.035	0.035	0.50–1.00	1.50– 2.00

SILICO-MANGANESE STEELS

S. A. E. Steel No.	Carbon Range	Manganese Range	Phosphorus, Max.	Sulphur, Max.	Silicon Range
9250	0.45–0.55	0.60–0.90	0.045	0.045	1.80–2.20
9260	0.55–0.65	0.60–0.90	0.045	0.045	1.80–2.20

STEEL CASTINGS

S. A. E. Steel No.	Carbon	Phosphorus, Max.	Sulphur, Max.
1235	As required by physical properties	0.05	0.05

NICKEL STEELS

S. A. E. Steel No.	Carbon Range	Manganese Range	Phosphorus, Max.	Sulphur, Max.	Nickel Range
2315	0.10–0.20	0.30–0.60	0.04	0.045	3.25–3.75
2320	0.15–0.25	0.50–0.80	0.04	0.045	3.25–3.75
2330	0.25–0.35	0.50–0.80	0.04	0.045	3.25–3.75
2335	0.30–0.40	0.50–0.80	0.04	0.045	3.25–3.75
2340	0.35–0.45	0.50–0.80	0.04	0.045	3.25–3.75
2345	0.40–0.50	0.50–0.80	0.04	0.045	3.25–3.75
2350	0.45–0.55	0.50–0.80	0.04	0.045	3.25–3.75
2512	max. 0.17	0.30–0.60	0.04	0.045	4.50–5.25

NICKEL-CHROMIUM STEELS

S.A.E. Steel No.	Carbon Range	Manganese Range	Phosphorus, Max.	Sulphur, Max.	Nickel Range	Chromium Range
3115	0.10–0.20	0.30–0.60	0.04	0.045	1.00–1.50	0.45–0.75
3120	0.15–0.25	0.30–0.60	0.04	0.045	1.00–1.50	0.45–0.75
3125	0.20–0.30	0.50–0.80	0.04	0.045	1.00–1.50	0.45–0.75
3130	0.25–0.35	0.50–0.80	0.04	0.045	1.00–1.50	0.45–0.75
3135	0.30–0.40	0.50–0.80	0.04	0.045	1.00–1.50	0.45–0.75
3140	0.35–0.45	0.50–0.80	0.04	0.045	1.00–1.50	0.45–0.75
3215	0.10–0.20	0.30–0.60	0.04	0.040	1.50–2.00	0.90–1.25
3220	0.15–0.25	0.30–0.60	0.04	0.040	1.50–2.00	0.90–1.25
3230	0.25–0.35	0.30–0.60	0.04	0.040	1.50–2.00	0.90–1.25
3240	0.35–0.45	0.30–0.60	0.04	0.040	1.50–2.00	0.90–1.25
3245	0.40–0.50	0.30–0.60	0.04	0.040	1.50–2.00	0.90–1.25
3250	0.45–0.55	0.30–0.60	0.04	0.040	1.50–2.00	0.90–1.25
3312	max. 0.17	0.30–0.60	0.04	0.040	3.25–3.75	1.25–1.75
3325	0.20–0.30	0.30–0.60	0.04	0.040	3.25–3.75	1.25–1.75
3335	0.30–0.40	0.30–0.60	0.04	0.040	3.25–3.75	1.25–1.75
3340	0.35–0.45	0.30–0.60	0.04	0.040	3.25–3.75	1.25–1.75
3415	0.10–0.20	0.45–0.75	0.04	0.040	2.75–3.25	0.60–0.95
3435	0.30–0.40	0.45–0.75	0.04	0.040	2.75–3.25	0.60–0.95
3350	0.45–0.55	0.45–0.75	0.04	0.040	2.75–3.25	0.60–0.95

CARBON STEELS

S. A. E. Steel No.	Carbon Range	Manganese Range	Phosphorus, Max.	Sulphur, Max.
1010	0.05–0.15	0.30–0.60	0.045	0.05
1015	0.10–0.20	0.30–0.60	0.045	0.05
1020	0.15–0.25	0.30–0.60	0.045	0.05
1025	0.20–0.30	0.50–0.80	0.045	0.05
1030	0.25–0.35	0.50–0.80	0.045	0.05
1035	0.30–0.40	0.50–0.80	0.045	0.05
1040	0.35–0.45	0.50–0.80	0.045	0.05
1045	0.40–0.50	0.50–0.80	0.045	0.05
1046	0.40–0.50	0.30–0.50	0.045	0.05
1050	0.45–0.55	0.50–0.80	0.045	0.05
1095	0.90–1.05	0.25–0.50	0.040	0.05
1350[1]	0.45–0.55	0.90–1.20	0.040	0.05
1360[1]	0.55–0.70	0.90–1.20	0.040	0.05

SCREW STOCK

S. A. E. Steel No.	Carbon Range	Manganese Range	Phosphorus, Max.	Sulphur Range
1112	0.08–0.16	0.60–0.80	0.09–0.13	0.075–0.15
1120	0.15–0.25	0.60–0.90	Max. 0.06	0.075–0.15

[1]The silicon content for steels No. 1350 and 1360 shall not exceed 0.30 per cent

This article written by the Norton Co. of Worcester, Mass.

FACTORS AFFECTING GRINDING WHEEL SELECTION

The selection of a grinding wheel for a given piece of work is not a guess—neither is it calculable by mathematics. In other words, grinding is still largely an art, although recently much progress has been made in uncovering and understanding certain scientific principles which apparently underlie correct grinding practice as we know it today.

Certain factors have to be considered in selecting a grinding wheel for a particular job. The wheel selected is specified by describing its abrasive, grit, grade and process. The chart below roughly summarizes those factors which have a bearing on the selection of the wheel, although it admittedly has to be very general because the different kinds of grinding such as cylindrical, surface, internal and offhand grinding are not treated separately.

I. TO SELECT THE ABRASIVE

Consider Factors such as:

- A. Physical properties of the material to be ground
  - Use Alundum Grinding wheels for materials of high tensile strength
    - Carbon steels
    - Alloy steels
    - High speed steels
    - Annealed malleable iron
    - Wrought iron
    - Tough bronzes
    - Tungsten, etc.
  - Use Crystolon Grinding wheels for materials of low tensile strength
    - Gray iron
    - Chilled iron
    - Brass and bronze
    - Aluminum and copper
    - Marble
    - Granite
    - Pearl
    - Rubber
    - Leather, etc.

2. TO SELECT THE GRIT

Consider Factors such as:

A. Amount of material to be removed	Use coarse wheels for fast removal of stock.
B. Finish desired	Use fine grain for fine finish, except in machine grinding operations.
C. Physical properties of material to be ground	Use coarse grain for ductile materials and finer grain for hard, dense, or brittle materials.

3. TO SELECT THE GRADE (DEGREE OF HARDNESS)

Consider Factors such as:

A. Physical properties of the material to be ground	Use hard wheels on soft materials and vice versa.
B. Arc of contact	The shorter the contact, the harder the wheel should be.
C. Wheel speed	The higher the wheel speed, the softer the grade and vice versa.
D. Work speed	The higher the work speed, the harder the grade should be and vice versa.
E. Condition of Grinding Machine.	Machines in poor condition require harder wheels than machines in good condition. Bearings must be kept adjusted. Foundation must be solid. Machine must be of rigid construction.
F. Skill of operator	Skillful operator can use softer wheels than unskilled man—softer wheels mean more economical production. Piece-work grinding usually calls for harder wheels than day work.

4. TO SELECT THE PROCESS

Consider Factors such as:

A. Dimensions of wheel	Wheels subjected to bending strains should be made by shellac or rubber process. Extremely thin abrasive saws must be made by the shellac or rubber process. Wheels over 36″ diameter are usually made by the silicate process.
B. Rate of cutting	Use vitrified wheels for most rapid cutting.
C. Finish desired	Use shellac wheels for highest finish, where rapid production is not a factor. Use silicate wheels to replace sandstones on cutlery, etc.

A resume of the factors outlined will indicate how impossible it is to make specific wheel recommendations in tabular form for the grinding of high speed and carbon steels, oil hardening and alloy steels and high chromium (stainless and rustless) steels. The best that can be done is to list grinding wheel recommendations to cover operations on parts frequently made from the steels mentioned. Such recommendations are contained in the table below. The column " First Selection " lists wheels which should be tried first. In making these recommendations we have taken it for granted that the wheel speeds are in accordance with accepted standards, that the wheels are of a size commonly used for the work, and that the machines are in good operating condition

RECOMMENDED WHEEL SPEEDS---S. F. P M

Cylindrical grinding	5,500—6,500
Internal grinding	5,000—6,000
Snagging and general offhand grinding	5,000—6,000
Surface grinding	4,000—5,000

Knife grinding	3,500—4,000
Hemming cylinders	2,100—2,400
Wet tool grinding	5,000—6,000
Cutlery wheels	4,000—5,000
Shellac, rubber, and bakelite cutting off wheels	9,000–12,000

ABBREVIATIONS USED IN THE FOLLOWING TABLE

Crys	CRYSTOLON abrasive
Alun	ALUNDUM abrasive
Vit	VITRIFIED process
Sil	SILICATE process
Rub	RUBBER process
Bak	BAKELITE process
Shel	SHELLAC process*

* Formerly referred to as Elastic process.

The numerals "66" placed before the grain number as "6646-L" indicate that the wheel is made of "66 ALUNDUM" abrasive

The numerals "38" placed before the grain number as "3846-K" indicate that the wheel is made of "38 ALUNDUM" abrasive

Grinding wheels are sometimes made of a combination of grains and are designated as, for example, 24 combination. A combination wheel with a mixture of fine, coarse, and medium grain sizes has a different cutting action from a straight-grained wheel and is desirable for certain operations, particularly cylindrical grinding. Such wheels are designated by 24C as 24C-K.

WORK AND OPERATION	ABRASIVE AND PROCESS	1ST. SELECTION GRAIN	1ST. SELECTION GRADE
Ball Races–Radial (Hardened Steel)	....	....	....
Finish Surfacing (Cups and Cyls.)	Alun. Sil.	3830	G
Cylindrical	Alun. Vit.	6646	K
Rough Grooving (Inner Race)	Alun. Vit.	6646	L
Finish Grooving (Inner Race)	Alun. Shel.	80	3
Rough and Finish Grooving (Inner Race, One Operation)	Alun. Shel.	80	3
Rough Grooving (Outer Race)	Alun. Vit.	6646	K
Finish Grooving	Alun. Shel.	80	4
(Outer Race)	Alun. Bak.	100	S3
Internal	Alun. Vit.	6660	K

WORK AND OPERATION	ABRASIVE AND PROCESS	1ST. SELECTION GRAIN	GRADE
Ball Races–Thrust (Hardened Steel)....			
Surfacing (Cups and Cyls.)............	Alun. Vit.	3830	J
Grooving..........................	Alun. Rub.	36	R8
Bits (Auger)			
Roughing End......................	Alun. Rub.	36	R8
Fluting...........................	Alun. Rub.	70	R8
Broaches			
Sharpening........................	Alun. Vit.	6646	K
Chasers (Thread)			
Surfacing.........................	Alun. Vit.	3846	J
Grinding Throats..................	Alun. Shel.	60	3
Chisels			
Surfacing (Cups and Cyls.)..........	Alun. Shel.	46	5
Edging (Cups and Cyls.).............	Alun. Vit.	60	M
Sharpening........................	Alun. Vit.	46	M
Cutters (Formed)			
(Gear)			
(Hob)			
(Inserted Tooth)			
(Milling)			
Sharpening........................	Alun. Vit.	6646	J
Dies (Threading)			
Chamfering (Cone Wheel)...........	Alun. Vit.	80	P
Dies (Drawing)			
Cleaning..........................	Alun. Vit.	60	L
Surfacing (Cups and Cyls.)..........	Alun. Sil.	3824	I
Surfacing (Straight Wheels)..........	Alun. Vit.	3846	I
Drills			
Cylindrical.......................	Alun. Vit.	50	N
Precision Sharpening..............	Alun. Vit.	46	L
Point Thinning....................	Alun. Shel.	50	2
Drills (Small)			
Fluting...........................	Alun. Rub.	46	R8
Offhand Sharpening................	Alun. Vit.	60	M
Drills (Large)			
Fluting...........................	Alun. Vit.	46	P
Offhand Sharpening................	Alun. Vit.	24	P
Gages (Plug Cylindrical)...............	Alun. Vit.	3880	K
Gages (U. S. Thread, Coarse Pitch)			
Grinding Threads..................	Alun. Vit.	38120	K
Gages (U. S. Thread, Medium Pitch)			
Grinding Threads..................	Alun. Vit.	38200	K
Gages (U. S. Thread, Fine Pitch)			
Grinding Threads..................	Alun. Vit.	38200	M
Knives (Butcher)			
Machine Surfacing.................	Alun. Shel.	50	4
Offhand Surfacing.................	Alun. Sil.	6680	K
Metallographic Specimens			
Roughing..........................	Alun. Vit.	80	P
Finishing.........................	Alun. Vit.	200	M

WORK AND OPERATION	ABRASIVE AND PROCESS	1ST. SELECTION GRAIN	GRADE
Reamers			
Backing-off	Alun. Vit.	6646	K
Cylindrical	Alun. Vit.	6646	K
Fluting	Alun. Rub.	80	R8
Roller Bearing Cups			
Cylindrical	Alun. Vit.	60	J
Internal	Alun. Vit.	3860	K
Rollers for Bearings			
Cylindrical	Alun. Vit.	100	O
Steel (Hardened)			
Cylindrical	Alun. Vit.	3824C	K
Surfacing (Cups and Cyls.)	Alun. Sil.	3830	G
Surfacing (Straight Wheels)	Alun. Vit.	3836	H
Cutting-off	Alun. Shel.	46	5
	Alun. Bak.	46	S4
Internal	Alun. Vit.	3860	J
Steel (High Speed)			
Surfacing (Cups and Cyls.)	Alun. Sil.	3830	G
Surfacing (Straight Wheels)	Alun. Vit.	3846	G
Cutting-off	Alun. Shel.	60	4
	Alun. Bak.	60	S3
Internal	Alun. Vit.	3846	J
Taps			
Fluting	Alun. Rub.	70	R8
	Alun. Bak.	70	S9
Sharpening	Alun. Vit.	46	M
Tools (Lathe and Planer)			
Light (Offhand)	Alun. Vit.	46	N
Heavy (Offhand)	Alun. Vit.	30	O
Using Large Wheels	Alun. Sil.	24	P
Automatic (Cup Wheel)	Alun. Vit.	24	L
Automatic (Straight Wheel)	Alun. Sil.	46	M

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